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AAA Quarterly Report
January–March 2001

LA-UR 01-2031

Los Alamos National Laboratory, Argonne National Laboratory
Oak Ridge National Laboratory, Sandia National Laboratories
Brookhaven National Laboratory, Lawrence Livermore National Laboratory
Burns & Roe, Enterprises, Inc., General Atomics, Westinghouse Savannah River Company
University of Nevada, University of Michigan, University of California, University of Texas

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Approval

Signature on File

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Edward Arthur
AAA Project Director
Advanced Accelerator Applications

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Acronyms

AAA	Advanced Accelerator Applications
ADS	Accelerator-Driven System
ADTF	Accelerator-Driven Test Facility
AES	Advanced Energy Systems (formerly Northrup-Grumman Corp.)
AET	Ability Engineering Technology
AHA	Acetohydroxamic Acid
ANL	Argonne National Laboratory
ANRC	Amarillo National Research Center
ANS	American Nuclear Society
APT	Accelerator Production of Tritium
ASME	American Society of Mechanical Engineers
ATR	Advanced Test Reactor
ATW	Accelerator Transmutation of Waste
BBE	Backbone Beam Enable System
BCCM	Bridge-Coupler Cold Model
BCM	Beam-Current Monitor
BCP	Baseline Change Proposal
BCP	Buffered Chemical Polishing
Beta (β)	Ratio to the speed of light
BNL	Brookhaven National Laboratory
BPM	Beam-Position Monitor
CCDTL	Coupled-Cavity Drift-Tube Linac
CCL	Coupled-Cavity Linac
CEA	Commision de Electricite Atomique (French)
CERCA	Compagnie Pour L'Etude Et La Realisation De Combustibles Atomiques
CLWR	Commercial Light Water Reactor
CMR	Chemistry and Metallurgy Research (facility at LANL)
CPI	Cost Performance Index
CTR	Cryogenic Test Rig
cw	continuous wave (100% duty factor)
DCR	Design Change Request
DDN	Design Data Need
EBR	Experimental Breeder Reactor
ED&D	Engineering Development and Demonstration
EEV	English Electric Valve
EIS	Electrochemical Impedance Spectroscopy
EIS	Environmental Impact Statement
EPICS	Experimental Physics and Industrial Control System
ERC	External Review Committee
ES&H	Environmental, Safety, and Health
ESSAB	Energy System Acquisition Advisory Board (DOE)
FZK	Forschungs Zentrum Karlsruhe (German Nat'l Lab)
FDD	Facility Design Description
HCP	Hazard Control Plan
GT-MHR	Gas Turbine Modular Helium Reactor
HEBT	High-Energy Beam Transport
HIP	Hot Isostatic Process (for bonding materials)
HPRF	High-Power Radio Frequency
HS/WS	halo-scraper/wire-scanner (diagnostic device)
I&C	Instrumentation and Control
ICS	Integrated Control System

INEEL	Idaho National Engineering and Environmental Laboratory
IOT	Inductive-Output Tube
ISTC	International Science and Technology Centre (Moscow)
JAERI	Japan Atomic Energy Research Institute
JCNNM	Johnson Controls Northern New Mexico
JLAB	Jefferson Laboratory (VA)
KEK	National Laboratory for High-Energy Physics (Tsukuba, Japan)
LAHET	Los Alamos High-Energy Transport
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LBE	Lead-Bismuth Eutectic
LBHM	Low-β Hot Model
LEBT	Low-Energy Beam Transport
LEDA	Low Energy Demonstration Accelerator
LLFP	Long-Lived Fission Product
LLNL	Lawrence Livermore National Laboratory
LLRF	Low-Level Radio Frequency
LMR	Liquid Metal Reactor
LWR	Light Water Reactor
MCNP	Monte Carlo N-Particle Transport Code
MCNPX	Merged code - Los Alamos High-Energy Transport (LAHET) and Monte Carlo N-Particle Codes (MCNP)
MEGAPIE	MEGAwatt Pilot Experiment
MTL	Materials Test Loop
n/p	neutrons per proton
NEPA	National Environmental Protection Agency
NERAC	Nuclear Energy Research Advisory Committee
NERI	Nuclear Energy Research Initiative
NFF	non-fertile fuel
O&M	Operations and Maintenance
ORNL	Oak Ridge National Laboratory
P&ID	Piping and Instrumentation Diagram
PACS	Personnel Access Control System
PFD	Process Flow Diagram
PNNL	Pacific Northwest National Laboratory
PPO	Plant Project Office
PRISM	Power Reactor Innovative Small Module
PSAR	Preliminary Safety Analysis Report
PSS	Personnel Safety System
PSI	Paul Scherrer Institute (Switzerland)
PUREX	Plutonium-Uranium Extraction
PWR	Pressurized Water Reactor
PYRO	Pyrochemical Process
Q	Quality Factor
QA	Quality Assurance
QAC	Quick ATW Costing
RAMI	Reliability, Availability, Maintainability, and Inspectability
RF	Radio Frequency
RFQ	Radiofrequency Quadrupole
RCCS	Resonance-Control Cooling System
RRR	Residual Resistance Ratio
RTTB	Room Temperature Test Bed
SAR	Safety Analysis Report
SC	Superconducting
SCRF	Superconducting RF
SDD	System Design Description

SEM	Scanning Electron Microscopy
SINQ	Spallation Neutron Source at Paul Scherrer Institute (Switzerland)
SNL	Sandia National Laboratory
SPI	Schedule Performance Index
SRS	Savannah River Site
SRTC	Savannah River Technology Center
STAYSL2	A computer code
T/p	Tritons (nucleii of tritium atoms) per proton
T/B	Target / Blanket
TEM	Transmission Electron Microscopy
TESLA	International Collaboration on a TeV Superconducting Linear Accelerator
TJNAF	Thomas Jefferson National Accelerator Facility
TMT	Target and Materials Test Station
TRAC	Transient Reactor Analysis Code
TRU	transuranics (plutonium, neptunium, americium, and curium)
TSF	Tritium Separation Facility
UFP	University Fellowship Program
UNLV	University of Nevada Las Vegas
UPP	University Participation Program
UREX	Uranium Extraction (an aqueous partitioning process)
URP	University Research Program
USQD	Unreviewed Safety Question Determination
WBS	Work Breakdown Structure
WNR	Weapons Neutron Research (facility at LANL)
WSRC	Westinghouse Savannah River Company
ZPPR	Zero Power Physics Reactor

Advanced Accelerator Applications
Quarterly Report
January–March 2001

I. Introduction

The Advanced Accelerator Applications (AAA) program is a new Department of Energy program commissioned last year by Congress. Los Alamos leads a national effort consisting of DOE laboratories (Argonne, Savannah River, Livermore, Oak Ridge), industry (Burns and Roe Engineering Inc, General Atomics) and universities (Berkeley, Texas, Michigan, Nevada). The program has been created to address pressing nuclear issues facing the United States:

- nuclear energy and waste management concerns
- declining US nuclear infrastructure
- global nuclear leadership
- national defense

The AAA Program was constituted by combining two programs: The Accelerator Production of Tritium (APT) Program and the Accelerator Transmutation of Waste (ATW) program. The APT Program was established in 1995 with a Commercial Light Water Reactor (CLWR) program as part of a dual-path strategy for development of a new tritium production technology for the nation. From 1995 through 2001, Defense Programs invested more than $600 million in design and development of an accelerator to produce tritium, including a full-scale prototype of the front-end of the accelerator. In December 1998, the Department chose the CLWR as the primary technology for tritium production, assigning APT the role of a backup technology. The AAA Program affords Defense Programs the opportunity to establish a robust backup technology to assure the nation's capability to produce tritium. The Accelerator Transmutation of Waste (ATW) program was funded by Congress in FY00 to investigate the feasibility of accelerator-driven systems to transmute long-lived toxic components of used nuclear fuel. Together, these two programs benefit each other by combining their technology developments.

The goals of AAA, over the next 10 to 12 years, are as follows:

- to continue technology development and demonstration applicable to a backup tritium production capability, should national security needs dictate.
- to demonstrate the proof-of-performance and practicality of transmutation of nuclear waste in terms of meaningful impact on nuclear materials and waste management; and
- to define and execute activities designed to support the country's nuclear science and engineering infrastructure.

A key future objective of AAA is the construction of an accelerator-driven test facility. The goal of the facility would be to demonstrate the transmutation of nuclear waste and also to function as a national nuclear science and engineering user facility.

II. Highlights

Low Energy Demonstration Accelerator (LEDA)

- **LEDA Beam-Halo Measurements -** All diagnostics and associated equipment were installed in the 52-quadrupole beam-halo channel. We operated with a matched 75-mA radio-frequency quadrupole (RFQ) output beam and intentionally introduced mismatch in the beam to measure the effects with eight halo-scraper, wire-scanner diagnostic devices, four of which are located at the center of the halo-channel magnet lattice and four at the end.
- **CCDTL Section 2 Fabrication -** We completed the fabrication of the coupled-cavity drift-tube linac (CCDTL) Section 2. The structure is currently undergoing post-braze tuning.

Target/Blanket and Materials

- **Professional Involvement -** An invited lecture entitled *The Effect of High Energy Protons and Neutrons on the Tensile Properties of Materials Selected for the Target and Blanket Components in the Accelerator Production of Tritium Project* was presented at the 2nd Japan Spallation-Materials Workshop held at KEK in Tsukuba, Japan.
- **Target Development –** The results of push-out testing on clad-tungsten rods have led to determining the HIP[1] temperature that promotes stronger bonding between the tungsten rods and the cladding.
- **Materials Testing -** Research completed at the University of Illinois has demonstrated that accurate crack-growth measurements can be obtained with the small-scale three-point-bend specimens irradiated at LANSCE.
- **Design Data Needs -** Three Design Data Needs (DDNs) related to contamination and cleanup of cooling systems, viz., *Production, Transport and Release of Helium, Hydrogen and Mercury for the TNS and Blanket Assemblies*, *Fluence-to-Dose Conversion Factors*, and *Radionuclide Release to Primary Coolants*, were completed. The light water corrosion work (DDN #30) was completed, and we discovered important implications for corrosion related to saturation effects in proton peak current—that the corrosion rates in the APT beam will be lower because of the beam's structure due to rastering.

High-Energy Linac

- **Spoke Cavity Development -** A formal design review of the superconducting β=0.175 spoke cavity was held at LANL. Concepts for couplers and cryomodules were chosen. An external review of the Accelerator-Driven Test Facility (ADTF) linac design has been scheduled to be held in April.

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[1] Hot Isostatic Process (HIP) for bonding materials

- **Cavity Testing -** We tested the spoke cavity on loan from ANL. Test results showed that cavity performance required for the ADTF low-energy linac can be achieved with spoke cavities.

Design Activities

- **Plant Site and Buildings -** Four Plant Site and Buildings System Design Descriptions (SDDs) were completed and released.
- **Linac Complex -** The Beam Diagnostics SDD and the Linac Maintenance Facility Equipment SDD were completed and released.
- **Integrated Control System -** The Integrated Control System (ICS) technical report was integrated into Section 2 of the ICS SDD.
- **Tritium Separation Facility -** The Glovebox Stripper SDD and the Isotope Separation SDD were completed and distributed for review.
- **Balance of Plant -** With the release of six significant design documents this quarter, including SDDs, P&IDs, general arrangements, and other documents, six level-3 milestones were satisfied.

Operations and Maintenance

- **ADTF Siting -** A response to the DOE-HQ letter requesting SRS site-specific information on siting the Accelerator-Driven Test Facility (ADTF) was prepared and will be submitted to DOE-HQ by DOE-SR.
- **O&M Requirements -** We distributed an updated version of the *Operations and Maintenance Requirements Document*.

Systems Engineering

- **Facility Design Description -** We revised and released the *Facility Design Description*, a level-2 milestone, ahead of schedule.
- **Plant-Level Availability and Maintainability Requirements Document -** We revised and released the *Plant-Level Availability and Maintainability Requirements Document*.
- **Preliminary Design Plan -** We revised and released the *Preliminary Design Plan*.

Environment, Safety, and Health

- **Requirements Documents -** The *Safety Requirements Document* and the *Environmental Design Requirements Document* were revised and distributed for review.
- **Environmental Impact Statement Development -** The EIS program plan was developed and incorporated into the Accelerator-Driven Test Facility (ADTF) CD-0 package.

Accelerator-Driven Test Facility

- **Critical Decision-0 -** The Critical Decision-0 (CD-0) package, a document that provides the summary information necessary to support the justification of mission need for the Accelerator-Driven Test Facility (ADTF), was submitted to DOE headquarters in March.
- **ADTF Requirements -** The ADTF Missions, Functions, and Performance Requirements document was subjected to numerous project team reviews and submitted to an independent expert panel chaired by Dr. Ron Omberg of PNNL.
- **ADTF Implementation Strategy -** As a result of continuing discussions with DOE on ADTF missions, a revised implementation strategy was developed that will base the conceptual design effort on a multiple-use facility to be designed and constructed in a phased sequence.
- **ADTF Collaboration -** Kickoff meetings were held with the French Commision de Electricite Atomique (CEA) to discuss collaborative efforts on the AAA Project. Several work areas were identified to initiate that effort.

Collaborations

- **MEGAPIE Collaborations -** A five-person delegation (DOE, LANL, ANL, BNL) represented the AAA Program in a MEGAPIE planning meeting at FZK, Karlsruhe. The group also visited PSI in Switzerland to see the SINQ accelerator and planned site for the MEGAPIE test.
- **French Collaborations -** An eight-member delegation (DOE, LANL, ANL) visited the French CEA facilities at Saclay, Cadarache, and Marcoule, and discussed collaborative efforts related to accelerator-driven systems (ADS) for waste transmutation. Five work packages were developed related to safety, physics, materials, fuels, and the ADTF.
- **Collaboration Strategies -** A report was prepared that summarizes the transmutation-related efforts ongoing in Europe and Asia, recommending strategies to best develop mutually beneficial collaborative efforts.

Transmutation Systems Integration

- **Requirements Document –** The report (and program deliverable) “Accelerator-Driven Transmutation of Waste (ATW): System Performance Requirements” was issued.
- **Safety -** An agreement was completed between a US DOE AAA Team and a French CEA ADS Team that includes a work package for Accelerator-Driven System (ADS) safety.

Separations Technology

- **AHA Behavior in the UREX Process –** We have advanced our understanding of acetohydroxamic acid (AHA) in the UREX process. AHA, which serves as a complexant/reductant, prevents the extraction of Pu and Np and permits the recovery of pure U in the first solvent extraction stage. Optical spectroscopy has shown that Pu is strongly tied up by AHA, possibly in the form of a polymeric compound, and we have found that AHA slowly decomposes in solution to acetic acid and hydroxylamine. These results provide valuable input for optimization of the process.

- **Hot Demonstration of UREX –** Arrangements have been made for using Dresden reactor spent fuel in storage at the Savannah River Technology Center (SRTC) for the FY02 demonstration of the UREX process. This eliminates the need for spent fuel shipments from other sites.

Transmuter Technology

- **Material Test Loop -** All major procurements for the Materials Test Loop (MTL) were completed, and a test plan was written. The MTL is ready for a readiness review and startup of operations next quarter.
- **POP Requirements Document -** The report (and program deliverable) "Accelerator-Driven Transmutation of Waste (ATW): Proof of Performance Requirements" was prepared and issued.

University Programs

- **University Fellowship Program –** The Amarillo National Research Center was contracted to administer the University Fellowship Program. A Call for Applications was published in the Commerce Business Daily and distributed to more than 150 University Departments. The ANRC established a website that is linked with the LANL and the University of Nevada Las Vegas (UNLV) AAA websites.
- **UNLV University Participation Program –** A two-day workshop was held at UNLV to introduce UNLV faculty to the AAA University Participation Program and to provide technical areas of interest for potential UNLV research. The University submitted to the DOE a proposal for the Participation Program, which was approved, authorizing the expenditure of funds.
- **Other University Programs –** Contracts were initiated with the Universities of Michigan, Cal Berkeley, and Texas to continue their support of AAA R&D. Seminars on AAA and ATW, including discussions of current and future academic programs, were presented at the Universities of Cincinnati, Wisconsin, and Minnesota.

Project Management

- **ADTF Review -** In February, Project Management hosted a successful external review of the Accelerator-Driven Test Facility (ADTF) Requirements held at UNM in Albuquerque.
- **AAA Quarterly Review –** The AAA Quarterly Review for the first quarter of FY01 was held in Los Alamos, February 6-7.

III. Scope and Technical Progress

1.01 Low Energy Demonstration Accelerator (LEDA)

Scope

Construction and operation of the Low-Energy Demonstration Accelerator (LEDA) will confirm the design and demonstrate the viability (at full power) of the most technically challenging components of the plant/facility accelerator. It will provide the first opportunity to look for possible beam halo at low energies (<8 MeV), develop a commissioning and operating plan for a cw (continuous wave) system, and prototype the entire low-energy plant/facility accelerator.

The LEDA beam activities will be conducted in three distinct stages (listed below). LEDA operates predominantly in continuous mode (cw), but short periods of pulsed operation are used during commissioning to permit use of interceptive diagnostics.

- **Stage I -** Installation and testing of a 75-keV, 110-mA proton injector. (Completed)
- **Stage II -** Addition of a 350-MHz radiofrequency quadrupole (RFQ) accelerator to accelerate a 100-MeV proton beam to 6.7 MeV. (Completed)
- **Stage IId -** Measurement of the formation and development of beam halo in a 52-quadrupole magnet lattice after the RFQ. Install the beam diagnostic gear necessary to measure beam halo. Verify that the equipment works correctly. Run low-duty-factor pulsed beam through the halo transport line. For various degrees of beam mismatch, measure detailed beam profiles at multiple points along the halo transport line. Using off-line analysis, compare the measured beam profiles with the profiles predicted by the beam-simulation codes. Use these results to make corrections (if needed) to beam codes.
- **Stage IIIa** - Addition of a 700-MHz coupled-cavity drift-tube linac (CCDTL) section to accelerate 6.7-MeV beam to ~8 MeV. This step will confirm the beam matching from the 350-MHz RFQ into the 700-MHz CCDTL, and will provide the first beam test with a 700-MHz RF system. Complete CCDTL structure fabrication, assembly, and tuning on sections 1 and 2 (to 7.28 MeV). Perform hot-model testing on section 2 only, to confirm that adding cooling channels near the coupling slots eliminates the progressive change in resonant frequency observed last year on the low-beta hot model.

Highlights

- **Beam-Halo Experiment -** All diagnostics and associated equipment were installed in the 52-quadrupole beam-halo channel. We operated with a matched 75-mA RFQ output beam and intentionally introduced mismatch in the beam to measure the effects with eight halo-scraper, wire-scanner diagnostic devices, four of which are located at the center of the halo-channel magnet lattice and four at the end.

- **CCDTL Section 2 Fabrication -** We completed the fabrication of the coupled-cavity drift-tube linac (CCDTL) Section 2. The structure is currently undergoing post-braze tuning.

Technical Progress

Diagnostics Gear for the Quadrupole Magnet Lattice

The remaining four of the nine halo-scraper/wire-scanner (HS/WS), dual-axis diagnostic devices were installed. The electronics that support these devices were also fabricated, installed, and checked out. A photograph of the completed beam-halo channel is shown in Figure 1. The HS/WS devices have one wire and two halo scrapers per unit.

Figure 1. A photograph of the 52-quadrupole-magnet lattice, looking from the HEBT (lower right) toward the RFQ (upper left). The four HS/WS assemblies at the end of the lattice, after magnets 45, 47, 49, and 51, are shown at the right of the photograph. The HS/WS assemblies located after magnets 20, 22, 24, and 26 are also visible in this photograph.

The central profile of the beam is measured with the wire (wire scan), and the profile in the periphery of the beam is obtained by using the halo scrapers, one on each side of the beam. The wire scanner data and the halo scraper data are acquired with overlapping position intervals and then joined to form one data file, giving about five orders of magnitude peak-signal-to-noise ratio for the beam profile measurements (Figure 2).

Preliminary Measurements of Beam Halo

The HS/WS devices were used to measure the profiles for the beam first injected into the magnet lattice. Based on these measurements, the matching quadrupoles were adjusted to obtain a better match. After two iterations, the beam size was uniform, 1.0 mm ±0.05, as measured with each wire scanner in the blocks of four HS/WS assemblies. A full beam profile for a 75-mA matched beam, obtained with both the wire scanner and halo scrapers at quadrupole magnet position #24, is shown in Figure 3. We then intentionally introduced a breathing-mode mismatch into the beam and measured the effects of that mismatch. As expected, we observed that the beam halo grows as the mismatch is increased.

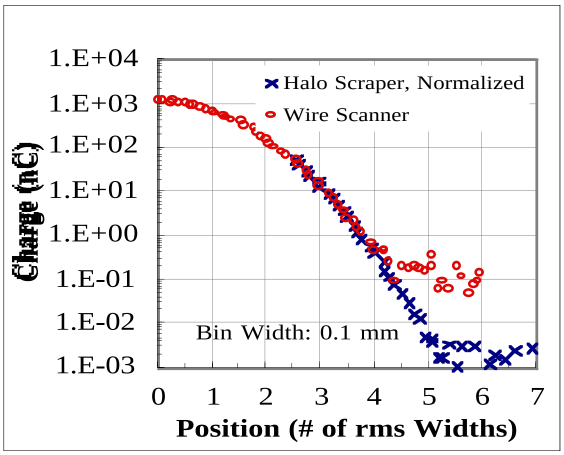

Figure 2. Simulated beam-profile distribution measurement. Wire placement, electronics noise, beam current, and position errors are included in this simulation. The wire scanner can detect beam to 4 rms widths: the halo scraper acquires another rms width.

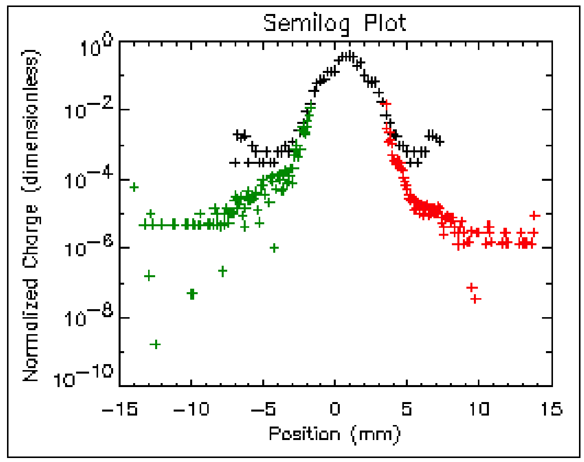

Figure 3. Measured "y" beam-profile distribution midway down the quadrupole magnet lattice. Black crosses are the wire scanner measurements; red and green crosses are +y and -y halo scraper measurements, respectively. The rms beam size is ~1.1 mm.

CCDTL Fabrication

All coupled-cavity drift-tube linac (CCDTL) section 2 cavities were stack-tuned, and then brazed together into one unit. A photograph of section 2 prior to brazing is shown in Figure 4. After brazing, CCDTL section 2 was sent to an Albuquerque machine shop to machine the vacuum flanges to their final dimensions. The finished assembly is back in Los Alamos being prepared for final post-braze tuning. The hot-model test stand is being prepared for installation of the structure. RF testing of that assembly is now scheduled for early June.

CCDTL section 1 fabrication is proceeding in the background. First stack tuning of that structure is now scheduled for July.

Figure 4. CCDTL section in the RF structures lab, prior to brazing. The stack tuning was performed with the structure in the vertical orientation, as shown.

Design Data Need (DDN) Documentation

We completed Design Data Need (DDN) #63, *700-MHz Circulator Performance Documentation*. A second DDN, #49, *RFQ Construction/Performance Documentation*, was split into two parts, *RFQ Construction Documentation* and *RFQ Performance Documentation*. A few remaining "as built" drawings will complete the RFQ construction documentation. A first draft of the RFQ performance document has been written. It will be completed in April.

Completion of DDN, #59, *LLRF Response to Amplitude Variations*, has been rescheduled for August. Experimental work on this DDN was deferred until after the beam-halo completion date so as to not impede the beam-halo measurements. Preparations for the experimental work are being completed; experimental work will be performed in June and July. The report will be completed in August.

1.02 Target/Blanket and Materials Studies Integration

Scope

Target/Blanket and Materials Engineering Development and Demonstration (ED&D) consists of a number of small projects addressing three primary topics for the plant designers:

- **Materials Behavior -** Characterize the mechanical, corrosive, and other properties of materials to be used in APT prototypic radiation environments. Materials studies are not limited to the target/blanket systems. Perform tests at the LANSCE Area-A high power target station, with analysis shared among a number of collaborating US laboratories. Certain issues involving light ions must be addressed such as tritium implantation, and production of hydrogen and helium in irradiated materials. The results of all Materials ED&D activities are contained in the APT Materials Handbook.
- **Radiation Transport Codes -** Improve and validate computer simulation codes and nuclear data for APT/AAA use. This involves work on the MCNPX Monte Carlo simulation code, extending the neutron and proton data table to 150 MeV, and performing a number of supporting cross-section measurements. Shielding and dosimetry questions particular to the APT environment are also addressed.
- **Target/Blanket Characterization -** Validate the computer predictions of n/p, T/p, radionuclide production, energy deposition, decay heat, and component activation through a program of measurement and simulation.

Highlights

- **Professional Involvement -** An invited lecture was presented at the Second Japan Spallation Materials Workshop held at KEK in Tsukuba, Japan, entitled *The Effect of High Energy Protons and Neutrons on the Tensile Properties of Materials Selected for the Target and Blanket Components in the Accelerator Production of Tritium Project*, discussing the effect of proton irradiation on the mechanical properties of Alloy-718, SS-316L, SS-304L, and Mod 9Cr-1Mo.
- **Materials Work -** The results of push-out testing on clad-tungsten rods have led to determining the HIP temperature that promotes stronger bonding between the tungsten rods and the cladding.

  Research completed at the University of Illinois has demonstrated that accurate crack-growth measurements can be obtained with the small-scale three-point-bend specimens irradiated at LANSCE.
- **Design Data Needs -** Three Design Data Needs (DDNs) related to contamination and cleanup of cooling systems, viz., *Production, Transport and Release of Helium, Hydrogen and Mercury for the TNS and Blanket Assemblies*, *Fluence-to-Dose Conversion Factors*, and *Radionuclide Release to Primary Coolants*, were completed. The light water corrosion work (DDN #30) was completed, and we discovered important implications for corrosion related to saturation effects in proton peak current—that the corrosion rates in the APT beam will be lower because of the beam's structure due to rastering.

Technical Progress

Professional Involvement

We presented two papers at the ASTM Small Specimen Effects Meeting in Reno, NV. One paper, *Use of Small-Scale Bend Samples for Evaluation of the Effects of High-Energy Proton/Neutron Irradiation on Mechanical Properties*, was on three-point-bend testing of irradiated SS-316L, Alloy-718 and F82H. The second paper, *Subsize Specimens for*

Fatigue Crack Growth Rate Testing of Metallic Materials, presented results demonstrating that accurate crack-growth measurements can be obtained with our LANSCE Area-A specimens, which are much smaller than those normally used in industry.

We also presented an invited lecture at the Second Japan Spallation Materials Workshop held at KEK in Tsukuba, Japan. The invited lecture, entitled *The Effect of High Energy Protons and Neutrons on the Tensile Properties of Materials Selected for the Target and Blanket Components in the Accelerator Production of Tritium Project*, discussed the effect of proton irradiation on the mechanical properties of Alloy-718, SS-316L, SS-304L, and Mod 9Cr-1Mo.

Hot-Cell Materials Analyses

The analysis of the 17B corrosion insert continued. The diameter of each corrosion probe was measured across the area where the proton beam impinged on it. To the accuracy of the measurement (±3 μm), no reduced diameter was observed on Al-6061-T6, Alloy-718 or SS-316L after irradiation for two months in the proton beam. Autoradiography was also performed on each probe to determine the beam location.

Work continued on the SS-304L-clad tungsten insert (Insert 18A). The diameter was measured on clad-tungsten rods across the location where the beam impinged on the rods. Once again, to the accuracy of the measurement (±3 μm), no reduced diameter was observed. Autoradiography was performed on these rods to determine the highest dose location.

We opened Insert 18B, the decay-heat insert, which held Alloy-718-clad tungsten rods. The tubes holding the clad rods were cut open and the clad rods removed for further analysis.

In preparation for testing the tungsten, the Instron testing machine was set-up for compression testing. The 5,000-lb load cell was installed and calibrated and a test performed on unirradiated tungsten.

Analysis of Materials at Collaborating Laboratories

Collaboration between the APT Materials Team and the Paul Scherrer Institute (PSI) to determine the fluence of specimens irradiated at SINQ has begun. Presently, the capabilities of the STAYSL2[2] package are being expanded to include more reactions from Al, Cu, Nb, Fe, Co, and Ni, as well reactions from Ti and Au-foil materials. The STAYSL2 package is a computer program that uses information obtained from gamma analyses of activation foils to determine the proton and neutron fluence.

Diffusion-Bonded Clad-Tungsten Rod Analysis

The analysis of the HIP-bond between SS-316L and tungsten continued. An SEM (Scanning Electron Microscopy) microprobe analysis was performed to determine the diffusion profile of SS-316L-clad tungsten, HIPed at 810°C and 900°C. The diffusion profile revealed a diffusion zone of 3 μm for the 810°C HIP and 7 μm diffusion zone for the 900°C HIP push-out specimens.

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[2] A computer code that will be used to analyze the results of the activation foil measurements in both a proton and neutron flux

A 20%-25% increase in the normalized push-out stresses (510−550 MPa) was observed for the specimens HIPed at 900°C when compared to those HIPed at 810°C (400 MPa). These results led to a recommendation that the HIP temperatures for the SS-316L-clad tungsten rods be increased from 810°C to 900°C, because push-out stresses are higher, meaning the bond is stronger.

1.04 High Energy Linac ED&D

Scope

The high energy linac ED&D scope is to develop and demonstrate superconducting RF linac technology that is required to build the Accelerator-Driven Test Facility (ADTF) linac for the AAA Program. Work in FY01 includes the following:

- **Spoke Cavity Development –** The spoke cavity is an accelerating structure that may be used at low energy, as low as ~7 MeV (RFQ exit energy) to ~100 MeV. Development work will lead to the design and fabrication of spoke cavities that will be beam tested on LEDA. Scope described here is contingent on an ADTF linac review to be held in April 2001.
- **Cavity testing –** Superconducting cavity testing is to be performed primarily in the LANL Superconducting RF Laboratory. In FY01, the cavities to be tested include mainly spoke-type cavities in support of spoke-cavity development. In addition, elliptical cavities will be tested to improve their performance. General-purpose instrumentation for cavity testing and the bench-testing of other components related to SCRF linacs will be developed.
- **Completion of SCRF APT DDN Work -** Work related to the development of APT SCRF high-energy linacs will be completed and documented, including the fabrication and testing of β=0.64 cavities and couplers.

Highlights

- **Spoke Cavity Development -** A formal design review of the superconducting β=0.175 spoke cavity was held at LANL. Concepts for couplers and cryomodules were chosen. An external review of the Accelerator-Driven Test Facility (ADTF) linac design has been scheduled to be held April 10-12.
- **Cavity Testing -** We tested the spoke cavity on loan from ANL. Test results showed that cavity performance required for the ADTF low-energy linac can be achieved with spoke cavities.

Technical Progress

- **Spoke Cavity Design -** The physics and engineering design of the β=0.175 two-gap cavity was optimized and is now considered to be final. A formal design review was held with a panel of experts from ANL, JLAB, and LLNL, who formally recommended that this design be adopted. Physics and engineering design of the three-gap cavities at β=0.20 and β=0.34 has been started.

- **Spoke Cavity Power Coupler -** The power coupler concept for the spoke cavities was selected. A single power-coupler design, based on the antenna-type (coupled into the cavity electrical field) used in normal-conducting applications at KEK/TRISTAN, will meet the 13.3-mA and 100-mA requirements of the three spoke cavity designs. This was confirmed by an informal conceptual design review held during this reporting period.

- **Spoke Cavity Cryomodule -** A "modular" cryomodule concept has been developed. This is based on an "axial assembly approach" which has been successful in many applications. The concept will accommodate four- and six-cavity configurations of the three-cavity designs by simply revising the cryomodule length. A tuner concept has been developed that will meet both the slow tuning and very fast tuning requirement. This cryomodule will fit into the existing APT linac tunnel design.

- **Spoke Cavity Cost Comparison -** Work on comparative cost estimates for normal and superconducting ADTF linac concepts continued. A preliminary review of costs was held at the Advance Energy Systems facility.

- **Spoke Cavity Testing -** The spoke cavity on loan from Argonne National Laboratory (ANL) was tested after modifying fixtures for performing BCP (buffered chemical polishing) and HPR (high pressure rinse) operations. This cavity had field emission starting around 5 MeV/m, but with helium processing, we were able to achieve an accelerating field of 12.5 MeV/m, which exceeds the ADTF linac specification ($Q=5x10^8$ at 5 MeV/m and 4 K) with ample margin. Also, low-field Q at 5 MeV/m was $1.5x10^9$ at 4 K, three times higher than the specification. This test demonstrated the feasibility of using spoke cavities for the ADTF linac low-energy sections. Diagnostics sensors for temperatures of the cavity surface and X-rays were installed as well as an X-ray energy spectrometer. The data from these devices have been analyzed to identify problems.

- **Elliptical Cavity Testing -** A 700-MHz, 5-cell superconducting cavity made by LANL was tested after BCP processing removed 100 microns. The result showed a low-field Q of $3.6x10^{10}$ at 2 K, which is the highest Q ever obtained before including the data obtained at JLAB. It implies that the ambient magnetic field is not the major cause of the lower Q values obtained at LANL compared to the ones at JLAB (JLAB data used to show ~35% higher low-field Q values). Though not yet confirmed, filling the cavity with de-ionized water and keeping it overnight after BCP is performed might have helped eliminate chemical residue more effectively and improved the Q values. This cavity reached 9.2 MeV/m, which is a significant improvement compared to the previous test. So far, we have observed that further etching of the surface can improve the performance to some extent, though not eliminate the field emission sources completely. A temperature sensor attached to the equator region of the middle cell showed a heating with high magnetic field that indicated a defect at the welding seam.

- **Prototype Cryomodule Test -** A cold box, on loan from BNL, was delivered to Los Alamos following the completion of modifications that were necessary to be able to test the prototype cryomodule. Also, the cryostat fabricated by Ability Engineering for the prototype cryomodule was received in Los Alamos.

- **Documentation -** Executive summaries of the final Design Data Need reports and drawing books of the APT cavity and coupler are being prepared.

1.05 Plant Site and Buildings

Scope

This WBS element consists of the civil, structural, and architectural design of the site infrastructure, principal operating buildings, such as the target/blanket building, accelerator tunnel and klystron gallery, and support buildings required for the operation of APT.

Highlights

- **System Design Descriptions -** Four Plant Site and Buildings system design descriptions (all level-3 milestones) were completed and released.

Technical Progress

- **System Design Descriptions -** The four system design descriptions (SDDs) revised and released this quarter include the Accelerator Tunnel SDD, the Site Improvements SDD, the Mechanical Service Building SDD, and the Accelerator Maintenance SDD.
- **Architectural Drawings -** We also completed comment resolution and revised the Accelerator Maintenance Building architectural drawings, and submitted the drawings for release.

1.06 Linac Complex

Scope

This effort continues the development of the preliminary design of the linac complex as follows:

- **Low Energy Linac –** Develop the preliminary designs of the RF cavities of the coupled cavity drift tube linac (CCDTL) and coupled cavity linac (CCL) by evaluating coupling characteristics, 3-D thermal/mechanical analyses, and cavity groupings to achieve a balanced RF, thermal, and mechanical design.
- **High Energy Linac –** Develop the cryomodule assembly and detail drawings for the 2- and 3-cavity cryomodules, performing thermal and structural analyses, developing a concept for the higher-order-mode coupler, preparing preliminary interface control documents (ICDs), and updating the SDD.
- **RF Power System –** Develop the preliminary design by preparing more detailed assembly and layout drawings of the klystron gallery and tunnel portions of the RF stations with emphasis on maintenance and access, adding water manifolds

in the gallery, revising the klystron specification and SDD, and developing algorithms for the low-level RF (LLRF).

- **Cryogenics System –** Develop the preliminary design by preparing preliminary ICDs, piping and instrumentation diagrams (P&IDs), developing assembly drawings of the cryogenic transfer lines and performing thermal-mechanical analysis on them.
- **Beam Diagnostics and Linac Maintenance Facility Technical Equipment –** Prepare Section 1 and Appendices B-C of the two SDDs.

Highlights

- **Milestones Completed -** The Beam Diagnostics SDD and the Linac Maintenance Facility Equipment SDD were released, satisfying two Level-3 milestones. All level-4 milestones scheduled during this quarter were completed.

Technical Progress

- **System Design Descriptions -** We updated and released the Beam Diagnostics SDD and the Linac Maintenance Facility Equipment SDD.
- **Low Energy Linac -** The resonance control cooling system (RCCS) configuration/layout drawings for the RFQ, CCDTL, and CCL were completed. We also completed a technical report on the CCL coupling-slot field enhancement.
- **Helium Cooling Circuit Analysis -** We completed a technical report documenting the analysis of a higher temperature, lower pressure helium cooling-circuit for the thermal shield in the cryomodule. The results show an approximate 8% decrease in electrical power required for the cryogenic plant. Additional benefits include less complex transfer-line design, improved safety, and a simplified refrigeration cycle.
- **RF Power Interfaces and Components -** We completed the drawings controlling the 700-MHz klystron cooling interfaces, which show the overall piping and instrumentation configuration and gallery layout, the revised klystron specification, and the maintenance report on RF components in the klystron gallery.
- **Interface Control Documents (ICDs) -** The ICDs for the AC power, water cooling, accelerator tunnel, and cryomodule were completed.

1.07 Target/Blanket Design

Scope

The target/blanket consists of the target and blanket assembly, associated shielding, heat removal and water purification systems, cavity vessel, remote handling system, instrumentation, and the beamstop systems. The primary function of the target/blanket is to convert a high-energy proton beam into a neutron source, and produce tritium from ^{3}He feedstock. During the current phase of the Project, the following activities are being performed:

- Prepare preliminary design packages, including design calculations, system-level analyses, design drawings, assembly drawings, process flow diagrams, and P&IDs, for the target/blanket system, cavity vessel, external shielding, heat removal and coolant purification systems, and the remote handling system
- Prepare and update system design descriptions (SDDs)
- Develop preliminary systems-level design and interface requirements
- Prepare preliminary general arrangement drawings
- Review and approve DDN test plans
- Complete initial prototype development and testing, prepare fabrication and development reports, and perform status reviews on the preliminary design
- Develop preliminary activation analyses and shielding requirements

Highlights

- **Documents and Drawings -** The following documents and drawings were completed and released:
  - Gas-tube weld-development report and the reports documenting the target/blanket thermal-hydraulic analyses (both Level 4 milestones);
  - *Cavity Vessel and Cavity Vessel Internals Configuration Selection* report, and cavity flood initial P&ID;
  - Target and blanket P&IDs for the Heat Removal System;
  - External Shield assembly drawing; and
  - *Process Development for Welding APT Aluminum Gas Tubes* report.

Technical Progress

- **System Design Descriptions -** We completed updates or drafts of the following documents and distributed them for review: the Target/Blanket SDD, External Shielding SDD and Window Heat Removal SDD. Revision of the Primary Coolant Purification SDD continued.
- **Tensile Test Data Analysis -** A simple method was developed for performing a statistical analysis of the tensile-test data developed from the LANSCE irradiation program to support calculating the target/blanket design stress allowables.
- **Stress Analysis -** Results of the stress analysis of the retractable window/window-housing assembly show maximum deflections of the seal surface along the top and bottom edge, well below the maximum deflection that the reference design E-seal can accommodate. The results also indicate that the cam mechanism design has sufficient stiffness to prevent excessive window-manifold deflections.
- **Prototyping -** The manufacturer of the Rung-1 prototype tungsten tubes has told us that they can deliver the prototype tungsten tubes by the end of the first week of June. This delivery would meet our revised detailed work schedule.

1.08 Integrated Control System (ICS)

Scope

The Integrated Control System (ICS) is the overarching supervisory control system. It integrates and coordinates plant control to the extent required to meet *Facility Design Description* (FDD) requirements. The ICS performs global and distributed functions. The global functions include providing supervisory control for all plant systems, operator interface, data and alarm management, self-checks and diagnostics data, a parameter save/restore function, automatic sequencing, closed-loop control and system tuning, mode control, and equipment protection. The distributed functions include the control and input/output processors connected to data highways linked to the systems within the accelerator, target/blanket, tritium separation facility (TSF), balance of plant, and main control room. During the current phase of the Project, the ICS scope includes the following:

- Prepare and release Revision C of the ICS SDD
- Prepare preliminary design packages including functional block and data flow diagrams, flow charts and control details for global and distributed functions
- Develop input/output channel counts and control loop detail database
- Identify and provide support to interfacing systems

Highlights

- **ICS Technical Report -** The ICS technical report was integrated into Section 2 of the ICS SDD. We have developed context diagrams for all ICS components.

Technical Progress

- **System Design Description -** Context diagrams showing the relationship of ICS components to one another were developed. Examples of ICS components include data acquisition, alarm manager, interfacing hardware, and timing system. We are also preparing function hierarchy diagrams for each of the ICS components for inclusion in the SDD.

- **Preliminary Design Status Report -** We submitted draft input for the ICS portion of the *Preliminary Design Status Report*.

1.09 Tritium Separation Facility

Scope

The tritium separation facility (TSF) separates pure tritium product from the mixture of hydrogen isotopes produced in the blanket by neutron capture in ^{3}He. The TSF includes a system to separate tritium from protium, gloveboxes to prevent losses from process equipment containing significant quantities of tritium or ^{3}He, a ^{3}He supply system, a system to package and ship tritium product, an analytical laboratory to support production and tritium accountability, and systems for processing waste gases and glovebox atmospheres. This design activity will produce all technical information needed to procure, fabricate, and construct the TSF. During the current phase of the Project, the TSF scope includes preparation of the following:

- Preliminary design packages, including design calculations, system-level analyses, trade studies
- Process flow diagrams (PFDs) and P&IDs
- Preliminary designs and design reports for key system components
- Equipment layout drawings and component drawings for TSF systems
- Preliminary general arrangement drawings
- Preliminary SDDs for TSF systems

Highlights

- **System Design Descriptions -** The Glovebox Stripper SDD and the Isotope Separation SDD were completed and distributed for review.

Technical Progress

- **System Design Descriptions -** Work continued on four TSF SDDs, *viz*., the Isotope Recovery System, Isotope Separation System, Glovebox Stripper System, and Helium Supply System. Major activities included:
  - Refining functions and preparing functional block flow diagrams
  - Incorporating changes in performance requirements
  - Adding component requirements
  - Updating and improving bases for functional requirements
  - Updating and expanding system descriptions
  - Adding component descriptions and component performance characteristics
  - Including relational information to construct traceability matrices

  The Glovebox Stripper SDD was due in February; however, comment resolution for this SDD has not yet been completed.
- **Preliminary Design Status Report -** We prepared the outline for the TSF input to the *Preliminary Design Status Report* and prepared a significant portion of the report input.

1.11 Balance of Plant

Scope

The balance of plant segment includes electrical, instrumentation and controls (I&C), mechanical, and nuclear systems.

Highlights

- **Milestones Completed -** With the release of six significant design documents this quarter, including SDDs, P&IDs, general arrangements, and other documents, six Level-3 milestones were satisfied.

Technical Progress

- **System Design Descriptions -** We revised and released both the Target/Blanket Storage Pool SDD and the Construction Power Supply SDD. Release of these SDDs satisfied two level-3 milestones.
- **Design Drawings and Diagrams -** Three level-3 milestones were met with the release of the Accelerator Tunnel System general arrangement drawings, Chilled Water System PFDs, and the Fire Protection System P&IDs.
- **Material Handling -** We completed and released the Klystron Material Handling Study, a level-3 milestone.
- **Electrical -** We completed design evaluation of the changes to the main power-supply system high-voltage, medium-voltage, and low-voltage single-line diagrams. We concluded that the overall power distribution scheme is not affected by new load data received for the plant systems, except for a need for the addition of a few motor-control centers. Both the *Electrical Design Criteria* and the Construction Power Supply System single-line diagram were completed.

1.14 Operations and Maintenance (O&M)

Scope

The Operations and Maintenance (O&M) focus is to assure the APT design incorporates both the legal requirements and the best practices for safe and effective facility operations. We provide this through input to the continued development of the APT design and associated Preliminary Design Package. O&M input includes participation in design review meetings, RAMI interaction, startup planning, as well as documentation reviews such as the FDD, SDDs, PSAR, PFDs, P&IDs, trade studies, and safety/QA documents. We provide liaison with Project teams, providing subject matter expertise in Savannah River Site (SRS) Conduct of Operations and site standards as follows:

- Provide real time O&M interface with the TPO and PPO at Los Alamos to ensure design evolution meets SRS standards
- Participate in appropriate design review and interface meetings and review of documentation
- Interface with O&M at SRS to ensure unity of input to the design teams
- Participate in working groups and teams as appropriate

Highlights

- **ADTF Siting -** A response to the DOE-HQ letter requesting SRS site-specific information on siting the Accelerator-Driven Test Facility (ADTF) was prepared and will be submitted to DOE-HQ by DOE-SR. This site-specific information will be used to determine field office locations to be considered in the *AAA Environmental Impact Statement* (EIS). We are supporting the AAA EIS, participating in planning sessions and providing data used for the APT EIS to serve as a basis for the AAA EIS.
- **O&M Reviews -** We worked with the PPO to gain timely concurrence on SDDs and other design documentation to meet PPO milestones. At monthly interface meetings, as well as special topical meetings, we continued to support advancement of preliminary design for the accelerator, target/blanket and balance of plant areas, and participated in the monthly design integration meetings.
- **O&M Requirements Document -** We distributed for review an updated version of the *Operations and Maintenance Requirements Document*, satisfying a WBS 1.14 milestone.

Technical Progress

- **System Design Descriptions -** We completed reviews of the SDDs for the Target/Blanket Building Storage Pool, Glovebox Stripper System, Site Improvements, Beam Diagnostics System, Mechanical Service Building, and the Radiation Exposure Protection System. We reached closure on comment resolutions for the Accelerator Facility Maintenance Building SDD, the Construction Power Supply SDD, the Mechanical Service Building SDD, and the Target/Blanket Storage Pool SDD.
- **Design Change Requests -** We completed reviews of Design Change Request DCR-0033, on a change in RF architecture, and DCR-0038, on accelerator tunnel and klystron window cooling.
- **Other Documents -** We reviewed the accelerator tunnel and Target/Blanket General Arrangement drawings, the Fire Protection System P&IDs, the *APT Electrical Design Criteria,* the construction power substation single-line diagram, and the *Plant-Level Availability and Maintainability Requirements Document.* We also reached closure to comment resolutions on the APT Cryogenic System/Accelerator Tunnel requirements ICD.

1.17 Systems Engineering

Scope

The objective of the systems engineering process is to ensure that the Project delivers an integrated and cost-effective design satisfying the DOE operational mission requirements and other externally mandated requirements. An important complementary role of systems engineering is to ensure that the diverse systems and components comprising APT/ADTF are compatible and will work together to meet functional, performance, and interface requirements. Early development of interface definition is essential to successful system integration.

The systems engineering process encompasses all aspects of preliminary design. The specialty disciplines include requirements management, plant-level analyses supporting requirements definition and plant optimization such as RAMI and facility protection, systems integration, configuration management, and system life-cycle costs.

Highlights

- **Facility Design Description -** We revised and released the *Facility Design Descriptio*n, satisfying a level-2 milestone ahead of schedule.
- **Plant-Level Availability and Maintainability Requirements Document -** We revised and released the *Plant-Level Availability and Maintainability Requirements Document*, a level-3 milestone.
- **Preliminary Design Plan -** We revised and released the *Preliminary Design Plan*, a level-3 milestone.
- **Documents Archived -** We successfully archived the first packages of APT documents, completing a level-4 milestone.

Technical Progress

- **System Design Descriptions -** We revised the procedure, *System Design Description, Preparation, Review, Approval and Release*. The revision incorporates improvements to SDD content and to the process used to develop SDDs. We conducted an SDD workshop at PPO-Oradell. Content of the workshop was similar to previous workshops, but also emphasized recent revisions in procedures and improvements in SDD preparation.
- **Preliminary Design Status Plan and Report -** We completed the annual update of the *Preliminary Design Plan*. Release of the document is being delayed until approval is obtained for the baseline change proposal (BCP) revising Project scope consistent with the revised plan. Also, we prepared and distributed to level-2 leads the first draft of the *Preliminary Design Status Report.* The report will reflect the status of the APT design as of the end of FY01. The report is scheduled for completion at the end of the fiscal year.
- **Facility Design Description -** We revised and released the *Facility Design Description*, satisfying a level-2 milestone. The FDD is the top-level requirements document that establishes the requirements for APT plant design. Significant changes to the FDD include:
  - A facility-level function flow-block diagram and revision of the top-level functions to be consistent with the diagram
  - Rephrasing of specific requirements to ensure consistent structure
  - Update of the Requirements Allocation Table, Appendix D
  - Elimination of requirements duplicated in the Safety Requirements Document

- Revision of the design description, Section 7.0, to reflect the current design

- **Plant-Level Availability and Maintainability Requirements -** We revised and released the *Plant-Level Availability and Maintainability Requirements Document*, meeting a level-3 milestone. The revision adds system-level availability allocations and updates the requirements to account for design evolution.

- **Availability Assessments -** We revised three reports: *Accelerator Calculation Report, Target/Blanket Calculation Report,* and *Balance of Plant Availability Calculation Report*. These reports give details and results of our availability analyses of the plant segments, and the basis underlying development of the duty cycle analysis. Completion of this documentation satisfies a level-4 milestone.

- **Archiving APT -** We began archiving hard-copy documentation from the APT Project. To date, we have prepared and submitted seven boxes of archived documents to the LANL Records Center. This successful test of the archiving process completes a level-4 milestone.

1.18 Project Management

Scope

Project management encompasses the following activities:

- Management and direction of design and supporting activities, consistent with approved work plans and baselines
- Project reporting, maintenance of plans and procedures, administration, information management, training programs, and facilities infrastructure
- Operation of cost and schedule monitoring and control systems
- Project acquisition strategy maintenance
- Support services, including contract and financial administration, computer system management, business management, and public affairs coordination
- Construction management support services including constructability reviews
- Quality assurance including implementing the *Quality Assurance Plan* and developing activity, trend, problem area, and non-conformance reports, and corrective actions.

Highlights

- **Baseline Change Proposal -** A baseline change proposal (BCP) for the remainder of the APT capital work was prepared and submitted to DOE.

- **ADTF Review -** In February, Project Management hosted a successful external review of the Accelerator-Driven Test Facility (ADTF) Requirements held at UNM in Albuquerque.

- **AAA Quarterly Review –** The AAA Quarterly Review for the first quarter of FY01 was held in Los Alamos, February 6-7.

Technical Progress

- **Baseline Change Proposal -** We supported preparation of a BCP to re-baseline APT for FY01. This BCP converts the work scope in the FY01 work packages into the new baseline, replacing the existing scope for FY01 and FY02 that had been part of BCP D001 (approved June, 1999).
- **ADTF CD-0 -** In support of the ADTF Critical Decision (CD)-0 package to be submitted to DOE, we prepared an ADTF funding profile for FY03-FY06, based on a construction start in FY04. We have also developed an accelerated start-of-construction schedule.
- **Close-Out Documentation -** We are reviewing and processing close-out documentation on contracts and purchase orders. Approximately 25 contracts and 1,250 purchase orders will be screened and closed out. This effort will continue into the next quarter.
- **Contracts -** We made a contract modification for Advance Energy Systems to support a preliminary comparative cost estimate of a superconducting linac alternative to the baseline normal-conducting linac design. We also awarded a contract to the University of Texas to qualify relative proliferation risks associated with the transmutation of actinides and long-lived fission products prior to geologic disposal.
- **Quality Assurance -** We began a quality assurance audit of the Project's work package planning and authorization process. The audit will continue into next quarter.

1.19 Environment, Safety, and Health

Scope

The objective of the ES&H process is to ensure facility safety, worker protection, environmental compliance, pollution prevention, and waste minimization for the APT/AAA Project. Efforts to achieve APT environmental objectives include preparation of the *APT Environmental Program Plan, Environmental Compliance and Permitting Plan*, *Waste Management Plan, Pollution Prevention and Waste Minimization Plan*, *ES&H Design Requirements*, and the *Environmental Impact Statement (EIS)*. The purpose of the safety program is to ensure the facilities provide protection for workers, the public, and the environment. The *APT Safety Implementation Plan* defines the process by which the safety program will be accomplished. The *Safety Analysis Report* (SAR) provides the formal documentation of the safety case for the facility.

Highlights

- **Requirements Documents -** The *Safety Requirements Document* and the *Environmental Design Requirements Document* were revised and distributed for review.
- **EIS Development -** The EIS program plan was developed and incorporated into the CD-0 package.

Technical Progress

- **Environmental Design Requirements Document -** We prepared and distributed for review a draft revision of the *Environmental Design Requirements Document*. This revision updates the document to assure its currency, remove any redundancies with the FDD, and to define the environmental functions, performance requirements and design requirements for the preliminary design of APT. Release of the document, scheduled for next quarter, is a level-4 milestone.
- **Safety Requirements Document -** We revised and distributed for review the *APT Safety Requirements Document*. Release of this document, planned for next quarter, is a level-3 milestone.
- **EIS Siting Report -** The siting report was started which will become input to the EIS and support a ROD for site selection for AAA.
  - Exclusionary criteria were established, and ten DOE sites meet these criteria.
  - The project prepared a letter that DOE -NE sent to the ten sites requesting their support for development in response to a questionnaire containing additional screening criteria to collect information on the ten sites.
  - Visits to all of the sites were started and will be completed in April. Based on the responses to the screening questionnaire and the site visits, a siting report will be prepared.
- **EIS Technology Report -** The EIS Technology Report was started. A project team was put together from all of the AAA organizations to collect the EIS input information about the project technology. A spreadsheet was developed and assignments were made for data to be collected by data type and facility segment. A process flowsheet was developed to guide the data collection for the AAA fuel-processing support facilities.

1.20 Accelerator-Driven Test Facility

Scope

The scope of work covering the pre-conceptual and conceptual design activities for the Accelerator-Driven Test Facility (ADTF) is as follows:

- **Design -** The ADTF design covers both the pre-conceptual and conceptual phases and will include the target/multiplier, accelerator, instrumentation and control, and balance of facility segments. The pre-conceptual design will support a Critical Decision-0 for the Project and the Approval of Mission Need, which is scheduled at the end of the second quarter of FY01. The conceptual design will commence thereafter and will continue throughout the remainder of the fiscal year ultimately leading to Critical Decision-1, Approval of Preliminary Baseline Range, at the end of FY02.

- **Systems Integration -** Integration activities include:
  - the development of the functional and performance requirements for the ADTF project
  - the definition and control of the design interfaces between the major facility segments
  - the coordination of internal and external design reviews
  - technical risk assessment
  - cost estimating
- **Project Management -** Project Management activities include:
  - definition and control of work scope
  - budget allocation and management
  - preparation and maintenance of integrated project schedules
  - issuance of periodic technical and management progress reports

Highlights

- **Critical Decision-0 -** The Critical Decision-0 (CD-0) package, a document that provides the summary information necessary to support the justification of mission need for the ADTF project, was submitted to DOE headquarters in March. The document described top-level facility functional and performance requirements, pre-conceptual design description of major systems, preliminary ranges for Project cost and schedule baselines, outyear funding profiles, technical risk, and NEPA/safety strategies. The document is being distributed for review in preparation for the DOE Energy System Acquisition Advisory Board (ESAAB) briefings in April.
- **ADTF Requirements -** The ADTF Missions, Functions, and Performance Requirements document was subjected to numerous project team reviews and submitted to an independent expert panel chaired by Dr. Ron Omberg of PNNL. This document will be revised and re-issued to incorporate the results of these reviews as well as the additional performance requirements to be imposed on the accelerator design.
- **ADTF Implementation Strategy -** As a result of continuing discussions with DOE on ADTF missions, a revised implementation strategy was developed that will base the conceptual design effort on a multiple-use facility to be designed and constructed in a phased sequence. A Target and Materials Test (TMT) station will provide material irradiation and coolant-testing capability, and will be first to operate. This will be followed by a 100-MW Subcritical Multiplier Assembly capable of supporting the ATW proof-of-performance testing program.
- **ADTF Collaboration -** Kickoff meetings were held with the French Commision de Electricite Atomique (CEA) to discuss collaborative efforts on the AAA Project.

Several work areas were identified to initiate that effort. The Project will submit to the CEA a summary report of the technical and design efforts to date by the end of April.

Technical Progress

ADTF Missions, Functions, and Requirements

The functions and requirements for ADTF were developed by analysis of the four primary AAA Program missions. Using a functional decomposition process, the functions are assigned to the appropriate facility segments. Where adequate basis exists, performance requirements or goals are assigned to each function. The ADTF Missions, Functions, and Requirements document has been issued as draft for internal and external project reviews. The DOE chartered an expert panel to review the requirements in a session held in Albuquerque in February. The requirements are scheduled to be issued and approved next quarter.

Target-Multiplier Design Options Trade Study

A preliminary trade study was conducted to evaluate the four candidate technologies for the subcritical multiplier. Decision criteria and weighting factors were developed to facilitate a systematic process of scoring to rank the design options. The design teams conducted the study, which was then presented to an Independent Review Panel for validation. Based on this evaluation, the design will proceed with the two preferred options – a sodium vessel concept and a modular concept. Two options (helium fast and helium fast-thermal hybrid) were eliminated from further consideration.

Target-Multiplier Design – Modular Concept

The configuration of the target-multiplier modular concept consists of a centrally located target/multiplier experimental cell surrounded by shielding and three adjacent hot-cells. The experimental cell contains the neutron spallation source and two multiplier segments on either side. During this quarter, the design team developed various design concepts for a spallation target and a coupled subcritical multiplier. To assess the feasibility of various concepts, neutronic and thermal hydraulic calculations were performed. In addition, a number of engineering layouts were generated with the primary goal of assessing remote handling and spatial allocation requirements.

Earlier sensitivity studies indicated that a 600-MeV beam is desirable to achieve an efficient coupling between the spallation target and the subcritical multiplier. With the target sized for a maximum beam power of 8 MW, the concepts for a lead-bismuth eutectic and a sodium-cooled tungsten target have now been quantified. The flexibility in the design allows testing of solid targets with a variety of coolants.

The emphasis of the physics studies has now shifted to the Target and Materials Test (TMT) station concept, which will integrate a spallation target with a smaller amount of blanket fuel sufficient for materials irradiation and coolant-loop testing.

Target-Multiplier Design – Sodium-Cooled Fast-Spectrum

The sodium-cooled fast-spectrum target-multiplier concept is based on a primary coolant (sodium) loop imbedded in a sodium pool or tank. The multiplier is placed in an inner vessel that is part of the primary loop with vertical beam entry from the top. The sodium-cooled multiplier has a very compact cross section (to meet neutron flux goals), and small-diameter target/buffer zones make it difficult to accommodate all the necessary equipment above the sodium tank (beam tube and shielding, control rod drives, and experimental loop equipment). Design work focused on the development of the fuel, experiment and target handling, and replacement operations. Layouts were developed to accommodate the lengths of the replaceable components (beam tube in particular) and to move and accommodate equipment (such as the experimental loops and multiplier inner-vessel cover) during the fuel- and target-handling operations.

Various concepts are being evaluated for the beam entry into the sodium vessel. As an alternate to a vertical entry, an angled entry is under consideration and development. This layout simplifies the fuel-handling operations, as it removes the accelerator beam tube and the copious shielding requirements away from the control-rod and fuel-handling equipment, but retains the integrity of the double-walled vessel containing the sodium pool. Horizontal entry does not appear to be viable due to the complexity associated with breaching and sealing the pressure boundary during target and/or window change-out.

Scoping physics calculations have been performed to determine the average and maximum multiplier-flux levels. The model employed is based on the core model previously developed and used for the EBR-II analysis. Parametric studies were performed to determine the effect of both the blanket size and fuel form on the flux values. Additional cases were calculated using an external-source diffusion-theory model. The target and buffer zones were explicitly represented in this model. Additional core neutronic calculations were performed to verify the impacts of reducing the number of assemblies and employing alternative fuel, more typical of an ATW facility. Neutron-physics calculations were initiated for the angled-entry design. The geometry (symmetry) of the core for this design differs considerably from the initial vertical entry design.

Critical Decision-0 (CD-0) Package

The efforts of the pre-conceptual design concluded with the issuance of the Critical Decision-0 (CD-0) package in March. The report will serve as the basis for the Justification of Mission Need for the ADTF and authorization to begin conceptual design. The CD-0 package provides a summary of the cost, schedule, and technical baselines at the pre-conceptual stage, but more importantly, provides the rationale for the facility missions. The report has been distributed to the various department heads at DOE headquarters in preparation for the DOE Energy System Acquisition Advisory Board (ESAAB) review and approval process.

Pre-conceptual Cost Estimate

The rough order-of-magnitude pre-conceptual cost estimate (with a TPC range of between $2.2–2.6B was prepared and submitted as part of the CD-0 package. The methodology of the cost estimate is detailed below.

Accelerator – The ADTF cost estimate will be scaled from the APT accelerator cost, taking into account the lower beam energy and current. Adjustments will also be applied to consider a higher accelerating gradient in the superconducting portion of the linac.

Target-Multiplier – Lacking adequate historical information for a parametric estimate, the APT target-blanket system was used as the basis with a very conservative contingency (100%) applied.

Balance of Facility – Appropriate scaling factors will be applied to the APT balance of plant systems and structures. The added cost for the deep excavation needed to accommodate a vertical beam entry will also be included.

1.21 Collaborations

Scope

An agreement has been signed between DOE and the French CEA that provides the framework for effective collaborations. A technical workshop is to provide a forum for discussions between technical leads of the U.S. and French programs, leading to written and technical collaborations.

Discussions will be initiated with other programs, including the European Union (EU), Germany, Italy, Switzerland, and Japan, with the objective of selecting key programs and initiating formal and informal collaborations on these programs. A report is to be provided recommending the potential areas for collaborations judged to be most promising.

Highlights

- **MEGAPIE Collaborations -** A five-person delegation (DOE, LANL, ANL, BNL) represented the AAA Program in a MEGAPIE planning meeting at FZK, Karlsruhe. The group also visited PSI in Switzerland to see the SINQ accelerator and planned site for the MEGAPIE test. The LANL portion of the delegation also visited Professor Waclaw Gudowski and his collaborators at the Royal Institute of Technology in Stockholm to discuss International Science and Technology Centre (ISTC) proposals related to transmutation.
- **French Collaborations -** An eight-member delegation (DOE, LANL, ANL) visited the French Commision de Electricite Atomique (CEA) facilities at Saclay, Cadarache, and Marcoule, and discussed collaborative efforts related to accelerator-driven systems (ADS) for waste transmutation. Five work packages were developed related to safety, physics, materials, fuels, and the ADTF.
- **Collaboration Strategies -** A report was prepared that summarizes the transmutation-related efforts ongoing in Europe and Asia, and recommending strategies to best develop mutually beneficial collaborative efforts. Because of the sensitivity of the content, the report is for internal use only.

Technical Progress

There is clear technical interest in the MEGAPIE collaboration, and Los Alamos expertise in spallation-target design and materials performance will be a welcome addition to the collaboration. However, there remain some contractual issues to be worked through before the AAA Program can become actively involved.

In collaborations with the CEA, five work packages were essentially finalized and work has begun. Planned future meetings have been factored into the matrix of proposed AAA Program international travel.

1.22 Transmutation Systems Integration

Scope

The scope of integrated transmutation systems is to balance system definition, design and engineering activities with safety, environmental, economic, proliferation, and institutional drivers.

- System definitions will integrate the system objectives of the decision framework to provide a solid technical foundation for programmatic decisions.
- Primary system trade-off studies on multi-tier approaches to transmuting spent nuclear fuel will be performed, including accelerator-driven systems for complete transmutation, and systems which include transmutation of plutonium in critical nuclear facilities and transmutation of actinides and fission products in accelerator-driven systems (ADS).
- Evaluating system objectives includes evaluating all elements of the functional baseline to integrate safety characteristics during normal and off-normal conditions; evaluating environmental impacts, waste-stream management issues, and impacts on the geologic repository; developing system models and computer codes that accurately characterize ATW economic performance; and quantifying the relative proliferation risks associated with the transmutation of actinides and long-lived fission products prior to geologic disposal.

Highlights

- **Requirements Document -** The report *Accelerator-Driven Transmutation of Waste (ATW): System Performance Requirements*, AAA-RPO-SYS-01-0015, was issued in March. The report is a program deliverable.
- **Safety -** An agreement was concluded in March between a US DOE AAA Team and a French CEA Accelerator-Driven System (ADS) Team that includes a work package for ADS safety.

System Definitions

Knowledge-mapping of transmutation-relevant technology and activities is being wrapped up and documented. However, methods for keeping the AAA Program abreast of technical advances in the domestic and international arenas of transmutation technology are being explored. A nuclear waste transmutation website is being generated that will include general information on waste transmutation, and listings of program documents pertinent to transmutation.

System R&D

Transmutation systems research and development (R&D) this past quarter included work on system performance requirements and multi-strata evaluations.

System Performance Requirements – *ATW System Performance Requirements* was issued. The requirements were developed using the ATW mission and decision objectives as bases, which in turn is the basis for the Proof-of-Performance Requirements document, also issued this quarter. While the system performance requirements (SPRs) are a combination of qualitative and quantitative requirements, depending on need, three fundamental assumptions were used in deriving the SPRs:

- Today's requirements are based on today's state of knowledge, and are subject to modification as knowledge increases and decisions are made
- Assume proof of performance testing initiates in 10 years
- Utilize Technology Readiness Level (TRL) development logic, functional baseline, and R&D mapping to the extent practical

The ATW/SPRs were derived using a hierarchy to clearly demonstrate derivation and lineage: however, no prioritization of requirements at the same level has been specified.

Multi-Strata Evaluations - Systems evaluations of multiple-tier fuel cycle scenarios to incinerate the transuranics (TRU) contained in LWR spent fuel were pursued this quarter. Two primary goals were identified for the multiple strata studies: 1) to reduce the number of ATW systems required to complete the mission, and 2) to enhance the performance of the final strata ATW system. Initial studies have focused on fuel-cycle options where the LWR TRUs remain mixed; fuel-cycle strategies utilizing more detailed separation of the TRU (e.g., PUREX) are considered a proliferation concern. A wide variety of reactor technologies (e.g., existing or advanced LWRs, gas-cooled reactors, liquid-metal cooled fast reactors) could be employed for the initial burning of the TRU material. Regarding TRU consumption, the key parameters are irradiation environment (fast or thermal), fertile material loading, and discharge burnup. Current studies have considered fast spectrum liquid-metal reactors (LMR) with fertile and non-fertile fuel, and thermal spectrum gas-cooled reactors (GT-MHR) with non-fertile fuel.

Results show that the multiple-strata options realize the primary goal of partial TRU consumption prior to the ATW campaign. In both systems, ~30% of the TRU mass can be consumed in a once-through first-strata irradiation. Discharge burnup is limited by irradiation damage to the structural materials in the LMR and by reactivity loss in the GT-MHR. A single recycle in each first-strata system was also evaluated. Isotopic changes from the first irradiation pass require an increase in enrichment for the recycled fuel; this leads to a reduced burnup when the recycled material is utilized.

It appears quite difficult to achieve improved ATW performance in scenarios where the LWR TRUs remain mixed. Using first-strata discharge as the ATW fuel, only small improvements in the reactivity loss rate in the ATW were observed with significant penalties in the ATW discharge burnup. Furthermore, large decreases in the TRU fissile content will require higher TRU loadings to conserve the multiplication factor which will challenge the dispersion fuel-particle fractions limits and likely require an alternative ATW fuel form.

Also this quarter, ATW system definition studies continued. The spent fuel characteristics of the sodium-cooled system point design were evaluated in detail to provide input for the fuels and separations development activities. Radiotoxicity parameters to quantify the environmental impact of waste transmutation were developed. Although the sodium-cooled transmutation concept has been chosen as the reference, systems studies continue on backup gas-cooled options. Initial work on a gas-cooled fast-spectrum multiplier design have focused on the choice of the primary vessel (steel or prestressed concrete) and design modifications that will enhance heat conduction pathways for the removal of decay heat.

Use of LWRs - The principle of the multi-tier system is to burn a portion of the long-term radionuclides in a reactor to provide more reliable electricity generation and then use an accelerator-driven system (ADS) to transmute the remaining nuclides once it becomes inefficient (too large a change in reactivity) to keep them in the reactor. Given enough infrastructure modifications, (extensions for plant operation, license modifications for Pu-containing fuel, etc.), it is feasible that existing LWRs could be used for this purpose. However, it may be more efficient to build new reactors and/or use a new fuel type (such as non-fertile) to complete the mission. Material streams of plutonium only and plutonium plus minor actinides have been examined, although the transmutation of long-lived fission products in this multi-tiered system has not yet been addressed.

In particular, calculations were performed to compare irradiation performance of three different types of plutonium-containing fuel in an LWR: mixed oxide (MOX), thorium/plutonium oxide, and non-fertile fuel (NFF). Three different actinide streams were used for the NFF: only the plutonium from spent fuel, plutonium plus neptunium, and all minor actinides combined. These studies were done with an infinitely-reflected nine-assembly model with plutonium-containing assemblies comprising one-quarter of a typical PWR core. One-third of the UO_2 was replaced every cycle, and the plutonium-containing fuel was removed after three cycles, separated, and sent to the ADS. Additionally, it is assumed that up to 80% plutonium burnup can be obtained in these systems and still meet safety and reactivity margins. However, it may turn out that recycle of the plutonium may be required to obtain this high of a burnup.

As shown in literature,[3] the burnup was highest for non-fertile fuel (80% plutonium), followed by thorium-based and mixed-oxide fuels. Mixed-oxide fuels, since they contain uranium, yielded the lowest burnup because, while destroying plutonium through transmutation of actinides, the uranium concurrently produces plutonium. Additionally, the burnup was largest when only plutonium (opposed to plutonium and minor actinides) was burned in the non-fertile fuel because more neutrons could be devoted to plutonium fissions than minor-

3 Shelley, A., et. al., "Parametric Studies on Plutonium Transmutation Using Uranium-Free Fuels in Light Water Reactors," Nuclear Technology, Vol. 131, pp. 197-209 (August 2000).

actinide transmutations. The burnup also influences the performance of the ADS (it has been determined that the less plutonium sent to the accelerator (compared to minor actinides), the smaller the change in reactivity for a given cycle length, reducing accelerator costs).[4] For this purpose, the performance of these three actinide material streams in the accelerator was compared after being burned in an LWR as non-fertile fuel. The reactivity swing (change in k_{eff}) in the accelerator when 82wt% of the plutonium was burned in the LWR (the Pu-only case) was only 0.015 per six months (note that without the use of a reactor, the swing over six months is 0.07), opposed to cases with plutonium plus neptunium (Pu + Np in NFF) and all minor actinides (MA in NFF), which doubled and tripled the reactivity swing, respectively, because the plutonium burnup was lower (see Table 2).

Table 1. Comparison of Non-Fertile Fuel Cases

Case/Param	MOX (Pu)	Th (Pu)	NFF (Pu)	NFF (Pu+Np)	NFF (MA)
Pu Burnup	30%	70%	82%	80%	69%
Actinide Burnup	5%	5%	75%	73%	74%
Power density Pu region	260-480 W/cc	250-450 W/cc	140-420 W/cc	140-420 W/cc	140-420 W/cc
Power density $U0_2$ region	190-460 W/cc	200-430 W/cc	200-540 W/cc	200-540 W/cc	200-540 W/cc

Table 2. Comparison of Material Going to the Accelerator-Driven System

	All MA in NFF	Pu + Np in NFF	Pu only in NFF
Np-237	0.02881	0.02312	0.15654
Pu-238	0.14911	0.06302	0.01788
Pu-239	0.03482	0.01492	0.00485
Pu-240	0.04405	0.01671	0.02849
Pu-241	0.05506	0.03491	0.03503
Pu-242	0.32738	0.23124	0.2021
Am-241	0.00345	0.31057	0.28152
Am-242	0.00005	0.00051	0.00046
Am-243	0.06488	0.09465	0.07851
Cm-242	0.00789	0.00329	0.00308
Cm-243	0.00062	0.00025	0.00023
Cm-244	0.23333	0.17836	0.17455
Cm-245	0.01997	0.0162	0.01006
Cm-246	0.01274	0.00765	0.00573
Δk_{eff} over 6 mo.	0.05	0.03	0.015

[4] H. R. Trellue, E. J. Pitcher, P. Chodak III, and D. Bennett, "Two-Tiered Approach for Light-Water-Reactor Waste Disposition Using Existing Light-Water Reactors and a Minor Actinide Burner," Los Alamos National Laboratory report LA-UR-01-1037 (February 2001).

System Demonstrations

Blue Room Tests - A review was completed of previous Accelerator Driven System (ADS) experiments. The review will provide direction for an experimental program aimed at furthering the understanding of ADS physics. Physics challenges were specified and the contributions and limitations of the existing experiments were identified; a U.S. program run successively at LANSCE and the Zero Power Physics Reactor (ZPPR) was outlined. Work continued on the assessment of the Purdue University Fast Breeder Blanket Facility (FBBF) fuel for the proposed Blue Room experiment at LANSCE. A key issue for the experiment is the multiplication factor of the configuration. An unmoderated system only allows a multiplication factor of ~0.69, much lower than the 0.9 employed in most ADS fast-spectrum transmuter designs. Alternative experimental configurations that utilize moderation to achieve a higher multiplication factor were explored. Results indicate that high multiplication factors can be achieved while retaining regions with a typical fast ADS spectrum.

Formulation of the motivation for subcritical experiments with pulsed proton beams continued. The Blue Room characteristics and proton beam structure appear ideal with sufficient availability to cover the preliminary target experiments (no fuel) that could be completed by December 2001. The essential MCNPX calculations have only just begun, and the following observations are made without benefit of such calculations:

- Pulsed-neutron measurements on similar materials with a D-T (deuterium-tritium) source give guidance as to the range of k_{eff} that can be considered.
- Another category of experiments, devised to address issues of radial power peaking, axial power uniformity, overall gain, and safety-related sensitivity issues are all thought to be valid with a multiplication of 10, although the essential MCNPX computations have not begun.
- From the neutronics and availability standpoint, 20% U-235 enriched metal castings have been suggested as promising fuel material for potential Blue Room experiments. An assembly can be configured from such material and required criticality measurements can be performed. A major consideration for such a bare assembly would be the degree to which room and support reflections can be minimized, in which case the zero-power dynamic response of the multiplier to the spallation source would be most evident.

System Objectives

Safety and Regulatory - During this quarter, an agreement was concluded between a US DOE AAA Team and a French CEA ADS Team that includes a work package for ADS safety. The agreement work scope has three major elements: (1) providing for safety by design in accelerator-driven systems, (2) developing the data necessary to support safety evaluations and decisions, and (3) developing and qualifying analytical tools.

Of these three work scope elements, the initial focus is developing matrices of postulated accidents and scenarios. The US DOE AAA and French CEA ADS agreement calls for developing both a generic event matrix and additional event matrices applicable to specific design concepts.

We have begun an effort to identify initiating events and the resultant scenarios for a design concept consisting of a lead-bismuth-eutectic target and a sodium-cooled blanket. To ensure a logical and structured process for identifying initiating events and the resultant accident scenarios, we are currently using an approach developed by the US Nuclear

Regulatory Commission (NRC) and applied during the pre-application safety evaluation for the Power Reactor Innovative Small Module (PRISM) liquid-metal reactor.

Early in the pre-conceptual and conceptual design process, detailed failure probabilities for each stage in an accident sequence are unavailable. Using the approach applied in the PRISM pre-application safety evaluation, an event tree is being constructed. The frequency of the initiating event can usually be estimated. Each sequence in the event tree can then be evaluated to determine its event category (EC) as a function of the initiating event frequency and the type and number of failures in the event tree. Events defined by such a deterministic process will eventually be supplemented with insights from probabilistic risk assessment evaluations.

A survey of accelerator-driven subcritical reactor-system design and safety characteristics has been initiated. The objective of this study is to identify the safety advantages and liabilities of accelerator-driven systems in comparison to accepted LWR and Liquid Metal Reactor (LMR) safety standards, and further to identify design characteristics that may be adopted or enhanced to provide safety margins for protection of the plant investment and the public. The accelerator has some significant advantages in its ability to rapidly shut off the beam. However, because the neutron source is independent of reactor conditions, source-driven subcritical systems lack an inherent shutdown mechanism. Thus, detection of reactor conditions and shutdown of the accelerator is a key safety consideration. The relevance of 10CFR50 Appendix A, General Design Criteria, was reviewed for relevance to AAA safety and licensing. In addition, preliminary investigations of the impact of helium generation in ATW fuel (high curium content) on gas pressurization and stress induced on the cladding were conducted.

Proliferation Resistance and Safeguards - The Delta model employed for economic evaluation of multi-strata options is being used as a base for proliferation assessments, using material-attractiveness levels. The potential technologies for application in the ATW fuel cycle were identified, and previous work on non-proliferation characteristics of the different stages of fuel treatment and waste form development were reviewed. To begin preparing an evaluation of the non-proliferation aspects of the ATW cycle, mass flows at various stages of the fuel cycle were calculated based on a typical LWR spent fuel composition and fractionation values developed by the ATW separations team. The initial list of non-proliferation attributes was taken from the TOPS[5] report on proliferation-resistant technology assessment. Preliminary attributes are being assigned to the discrete fuel-cycle steps based on a comparison of qualities of ATW materials with the various reactor cycles.

Environment, Waste Management, and Repository - The focus of this activity has been the development of system-level performance criteria based on benefit to the US geologic repository program. A draft *Geologic Repository Impact Metrics for ATW* defines quantitative requirements for ATW to provide benefits to the repository. A meeting with DOE-RW has been requested to discuss this draft. These requirements and the supporting discussions have been summarized into the System Performance Requirements draft document along with requirements from other considerations. These requirements then provide the basis for Proof-of-Performance Requirements and ADTF facility requirements.

Consideration of non-repository environmental impacts has resumed in cooperation with the ADTF EIS studies.

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[5] Report of the International Workshop on Technology Opportunities for Increasing the Proliferation Resistance of Global Nuclear Power Systems

Economics - The Quick ATW Costing (QAC) model was developed in the first quarter of FY01 to analyze the economic consequences of producing electricity versus not producing electricity. The conclusion of this study was that the revenue from the sale of electricity was greater than the cost of making the accelerator reliable and, hence, making the power firm. A description of the QAC model and these results were published in January 2001.[6]

A set of economic requirements was developed for ATW.[7] The main economic requirement is to optimize ATW economic factors sufficient for market penetration, if possible, subject to environmental, safety, and proliferation constraints. This economic optimization will utilize multiple strata options. Also, technological uncertainties and risks are to be minimized to the extent practical.

1.24 Separations Technology

Scope

Separations technology consists of three tasks addressing the various stages in the process of partitioning irradiated fuels for subsequent fissioning of transuranic elements and transmutation of long-lived fission products. The tasks are:

- **Light Water Reactor Spent Fuel Treatment –** This task involves the development and demonstration of efficient and economic means for the separation of uranium, transuranic elements, specific long-lived fission products, and other fission products from LWR spent fuel. An aqueous partitioning process (UREX) is envisioned for the initial treatment of LWR fuel, which involves the extraction of uranium for disposal as a low-level waste. This will be followed by a pyrochemical process (PYRO-A) to separate the transuranic elements from fission products.
- **Transmuter Blanket Fuel Treatment** – Non-fertile blanket fuel that has been irradiated in the AAA transmuter to fission transuranic elements must be processed to recover and recycle the unburned transuranics and to extract newly-generated long-lived fission products for transmutation. This task accomplishes the development and demonstration of the means for processing that blanket fuel. A pyrochemical process (PYRO-B) is planned for the separation of unburned transuranics and long-lived fission products. Such processes are favored because the reagents are stable under high radiation fields and because the processes are normally operated at elevated temperatures with the use of molten salts.
- **Waste Form Production –** One of the overarching criteria for AAA separations technology development is the minimization of high-level waste generation. Design of the LWR fuel treatment process has been oriented toward the

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[6] Charles. G. Bathke, "The Quick ATW Costing (QAC) Model and Electricity Production Versus Non-Production," Los Alamos National Laboratory document LA-CP-01-0111 (January, 2001). Also, Advanced Accelerator Applications (AAA) report AAA-RPO-SYS-01-0016 (January, 2001).

[7] Deborah Bennett, Bill Halsey, Yousry Gohar, "Accelerator-Driven Transmutation of Waste (ATW): System Performance Requirements," Advanced Accelerator Applications (AAA) report AAA-RPO-SYS-01-0015 (March, 2001).

elimination of liquid high-level waste streams, and the pyrochemical processes are similarly being designed to minimize high-level waste volumes. This task involves the development and qualification of durable high-level waste forms to accommodate the two principal waste streams (salt and metal) that emanate from the separations process as well as the waste form for the disposal of the pure uranium extracted from the spent LWR fuel.

Highlights

- **AHA Behavior in the UREX Process –** We have advanced our understanding of acetohydroxamic acid (AHA) in the UREX process. AHA, which serves as a complexant/reductant, prevents the extraction of Pu and Np and permits the recovery of pure U in the first solvent extraction stage. Optical spectroscopy has shown that Pu is strongly tied up by AHA, possibly in the form of a polymeric compound, and we have found that AHA slowly decomposes in solution to acetic acid and hydroxylamine. These results provide valuable input for optimization of the process.
- **Hot Demonstration of the UREX Process –** Arrangements have been made for using Dresden reactor spent fuel in storage at the Savannah River Technology Center (SRTC) for the FY02 demonstration of the UREX process. This eliminates the need for spent fuel shipments from other sites.

Technical Progress

UREX Process Development

Experimental spectrophotometric studies of AHA-actinide complexation behavior revealed that the AHA complexes with Pu(IV) and Np(IV) might be polymeric species. Figure 5 shows the broad lines of the absorption spectrum for the Pu(IV)-AHA complex(es). This information may provide an explanation of why the first set of analyses for plutonium provided poor mass balance for plutonium (and, to a lesser extent, for neptunium) during the batchwise verification of the UREX flowsheet.

Upgrading of an existing solvent-extraction-process computer model to include the UREX process is in progress. Literature data are being assessed, and experimental data are being collected where required. AHA complexation equations and constants for the important feed components are required to develop models that predict the distribution coefficients for U, Pu, Tc, and Np for the UREX process. Upon comparing data from different sources, discrepancies were found in the acid disassociation constant (pKa) for AHA. Given that the complexation constants are written as a function of pKa, it is necessary to determine this value experimentally. Distribution coefficients measured at ANL for U(VI) and at SRTC for Pu(IV) are being used to determine values for the complexation constants for AHA and these cations. With these data and a dozen or so new data points, it will be possible to calculate complexation constants for use in modeling. The computer model will then provide a cost-effective means for testing process improvements.

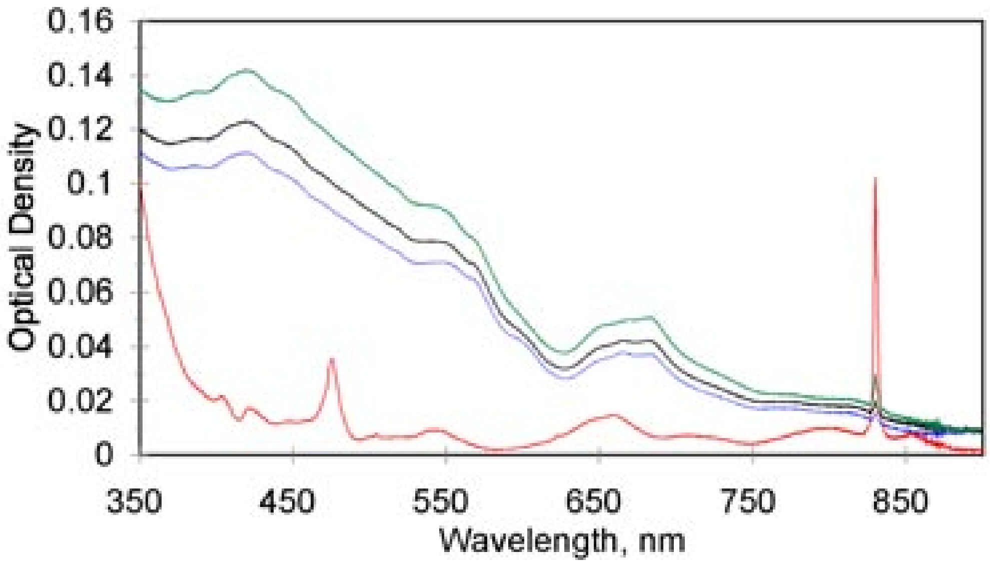

Figure 5. Absorption spectra of plutonium in 0.17 M AHA and 1 M nitric acid. The initial spectrum in 1 M nitric acid is the bottom curve and is ~80% Pu(IV) and 20% Pu(VI). The topmost curve is the initial spectrum obtained after the addition of AHA followed by spectra taken at four-hour intervals. Eventually, this intermediate spectrum disappears and evolves into the absorption spectrum for Pu(III), due to reduction of the plutonium by hydroxylamine, the hydrolysis product of AHA.

PYRO-A Process Development

Reduction of rare-earth fission product oxides to metal is an important consideration in selecting a reference process for PYRO-A. Thermodynamic calculations show that the reduction of rare-earth oxides by lithium metal is only feasible at extremely low Li_2O concentrations in the salt phase, <0.06 wt%. One way of maintaining this low Li_2O concentration is to continually remove the oxide ions from the salt phase as they are formed in the reduction process. Conceptually, this can be accomplished by electrochemical means. During this reporting period, an electrochemical-reduction experiment successfully demonstrated the technical feasibility of this concept. The electrochemical reduction experiment was performed at 650ºC with Nd_2O_3, a representative rare-earth oxide. Plateaus in the voltage-current relationship occurring at potentials progressively closer to the lithium potential indicate that there are different reaction steps. This understanding makes it easier to optimize the process.

Treatment of Wastes from the PYRO-A Process

In FY00, systems engineering studies of the PYRO-A process options had identified the potential for degradation of the zeolite on which the ceramic waste form is based as a major showstopper for the calcium-based process option. Recent X-ray diffraction data from an ion-exchange experiment revealed that there is no evidence for Zeolite 4A decomposition in the presence of calcium chloride. This result, although preliminary, makes the calcium-based oxide-reduction method a promising option for the PYRO-A process.

Development of Process for Treatment of Nitride-Based Transmuter Fuels

A conceptual process has been developed for the treatment of transmuter-blanket nitride fuel consisting of TRU nitrides dispersed in ZrN. A two-stage electrorefining process is proposed in which the first stage involves the collection of metallic TRUs at a solid or liquid cathode. Liberated N-15 gas is collected in the electrorefiner cover gas for recycle to the fuel fabrication process. The ZrN remaining after the first stage is then electrorefined in the second stage to collect metallic Zr and separate it from fission products. Both the metallic Zr and the N-15 released from ZrN are then recycled to fuel fabrication.

1.25 Transmuter Development

Scope

A transmuter, as defined within the context of accelerator transmutation of waste (ATW), is a subcritical nuclear reactor driven by a spallation neutron source. Transmuter development work consists of a number of elements aimed at developing a set of technologies, which, when integrated together, would result in the design of an efficient transmutation system for spent nuclear fuel. The four major elements of this WBS and the associated scope are as follows:

- **Integration and Analytical Support -** Integrate the various activities for the transmuter development into a common framework, including the implementation of the long term R&D plan and the development of the requirements for the specific research activities.
- **Target/Blanket Design and Development -** Develop the analytical methods for the nuclear and thermal-hydraulic design of the transmuter. For nuclear design, efforts are focused on nuclear design codes and data as follows: (1) evaluation of the fission cross sections of the key Pu isotopes, including a new ^{239}Pu ENDF evaluation with improved data, and support of the McGNASH code for the evaluation work; (2) improvement for lead-bismuth scattering cross-sections; (3) improvement of the subactinide fission and fission-fragment model for MCNPX; (4) benchmarking results and comparing with higher order methods (MCNPX); and (5) coupling higher order and deterministic codes, and revisions to deterministic codes, to account for subcritical source-driven behavior. For thermal-hydraulic system models, the liquid-metal and gas-system codes developed in FY00 are being assessed. The assessment includes benchmarks and quantification of some of the transport equations (thermal transients, decay heat in the coolant, oxygen control, and spallation products).

  Note that pending the decision on the import of a target from Russia to the US, activities associated with the International Science and Technology Centre (ISTC) lead-bismuth eutectic (LBE) were suspended in November, 2000. As of the end of the second quarter of FY01, no decision has been made.
- **Fuel Development -** This scope involves the fabrication and performance assessment of transuranic fuels. In FY01, the emphasis is on fabrication techniques and characterization of metallic and nitride fuels. The fabrication work mainly emphasizes the Pu-Zr or PuN, but inclusion of the other actinides is

also considered. Preparation for potential irradiation in a thermal reactor (the Advanced Test Reactor, ATR) starting in FY02 also is within the FY01 scope. For the coated particle fuels, an initial assessment of the technology in reference to transmutation applications is being performed. In FY01, the scope entails long-lived fission-product target development activities and is limited to the installation of an inert atmosphere glove box that will be subsequently used to fabricate technetium and iodine targets.

- **Materials Development -** This scope involves corrosion studies and radiation damage on materials. This is of interest especially for materials used in or around the spallation targets. In FY01, the major effort has been the completion of the Material Test Loop (MTL) and the start of the testing in this loop. In addition, some high temperature structural testing of already irradiated materials (at low temperature) are being conducted. The Materials Handbook will be maintained and the scope will be expanded to include additional materials of interest to ATW applications.

Highlights

- **Material Test Loop -** All major procurements for the Material Test Loop (MTL) were completed, and a test plan was written. The welding is complete. The MTL is ready for a readiness review and is expected to start operations in the third quarter.

Issues

- **Russian LBE Target -** A decision with respect to the import of the Russian LBE target must be made soon. The Russians are still working on finishing up their testing before exporting the target to the US.
- **ORNL Funding –** Oak Ridge National Laboratory (ORNL) personnel have not received their funding to conduct the high-temperature material testing tasks.
- **LLFP Target -** Unexpected safety problems (positive USQ) resulted in the delay of the planning and construction of the inert atmosphere glove-box installation for the long-lived fission-product (LLFP) target development.

Technical Progress

Integration and Analytical Support

As part of a larger team, two trips were taken to Europe related to the MEGAPIE initiative and the collaboration work packages with the French CEA. MEGAPIE involves an LBE target-development project. The project is at the preliminary design stage and the target will be used as a spallation neutron source at PSI (Switzerland). The MEGAPIE target and the associated design and development activities will have a strong positive impact on the US efforts in developing an LBE target. Multiple work packages were agreed upon for collaboration with the French CEA. The two work-packages that have direct impact on the transmuter development are in the areas of dedicated fuels (transmutation), and target and materials development.

Analytical Support - An extensive target/buffer design study was performed to evaluate the impact of buffer thickness on transmuter performance. Neutron source distributions, source importance, ATW system performance parameters, and neutron damage rates were evaluated for a parametric variation of the LBE buffer thickness from 11.5 cm to 28.5 cm. The source importance increases significantly (~20%) as the buffer thickness is reduced, implying a reduced accelerator current requirement. In addition, the system performance improves in many ways; for example, the reactivity losses decrease by ~10%. However, the reduced buffer thickness results in large (~50%) increases in the discharge fluence. In addition, the hydrogen and helium gas production in the structural materials increases even more severely, as high-energy neutrons dominate these reactions. More detailed investigation for the trade-off is recommended.

Additional thermal-fatigue analyses for the ATW subcritical core were performed to account for the high thermal conductivity of the ATW metal-dispersion fuel form; this increases the temperature difference at the above-core load pads, adversely impacting their cycle fatigue limit.

The ATW target design trade study was completed.[8]

A LANL staff-member is on temporary assignment at PSI (Switzerland) working on determining the fluence of specimens irradiated in STIP I (at PSI). In order to do this, he has expanded the capabilities of the analytical model (STAYSL2) package to include more reactions as well as titanium and gold because these activation foils were included in the PSI irradiation.

Target/Blanket Technology Development

Nuclear Design Tools - Final updates and corrections were made to the ETOE2-2 and MC^2 code packages to process ENDF-B/VI nuclear data. Verification tests for ENDF-VI multigroup cross-section data generated by MC^2-2 have been performed. Eigenvalues and reaction rates have been evaluated for six criticality benchmarks: Godiva, Jezebel, Bigten, and Flattop- Pu, 18, and 25. Results were compared to the state-of-the-art Monte Carlo codes MCNP and VIM using their ENDF/VI libraries. In addition, validation tests based on ADTF fuel compositions and MUSE[9] subcritical experiments were initiated. Preliminary results indicate excellent agreement with the higher-order results. Also this quarter, a higher harmonics calculation was introduced in the VARIANT option of the DIF3D package; this function is essential in evaluating the instability characteristics of an ADS system. Validation studies indicate that eigenvalue results using this technique agree well with analytical solutions. Improved methods to treat low material density regions (e.g., beam tube) in the variational nodal transport code are also being explored.

The work on the intranuclear cascade code improvements continued. We incorporated into CEM2K code, the use of realistic binding energies for the nucleons at the intranuclear stage of reactions. Also, we incorporated the use of reduced masses. Both refinements were tested favorably against existing data. We have developed new algorithms that allow the use of a number of different systematics for inverse cross-sections used in the complex-particle (e.g., alpha particles) models.

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[8] LA-UR-01-1634, "Preliminary Assessment of Spallation Target Options for Accelerator-Driven Transmutation", by C. Ammerman, X. He, M. James, N. Li, V. Tcharnotskaia, S. Wender, and K. Woloshun.

[9] ZERO Power critical experimental facility in Cadarache, France

We continued improvements to the McGNASH nuclear reaction code to model the fission decay and particle emission. We made progress incorporating width-fluctuation models by studying three different theories. We concluded that the Moldauer model is the best approach as it is simple to implement and provides fairly accurate predictions, comparable to more complex models (e.g., Weidenmuller model).

For the cross-section evaluation work, we have completed a new ENDF (n,f) evaluation of the ^{239}Pu fission cross-section, by using all available experimental data (including recent measurements from LANSCE). This work uses advanced statistical methods to evaluate the cross-section and its uncertainties, and will result in more accurate predictions for criticality in ATW applications. There are more LANL fission-data that we are considering before we finalize this work.

Thermal Design Tools - In the area of thermal-design, a number of test problems were completed for the Transient Reactor Analysis Code (TRAC). A number of minor problems were fixed for the sodium equations-of-state. A time-step limiter was added for cases where the axial conduction (explicit) in the fluid is invoked. There were no difficulties in the LBE test problems that were run. Input decks for both the ADTF LBE target and sodium-multiplier loops (corresponding to the pre-conceptual design for the modular option) were created and are setup to look at beam interrupts of arbitrary length and the thermal cycling that occurs.

Fuel Development - A Fuel Development Working Group (FDWG) meeting was held. The topics discussed in the meeting were: (1) ADTF fuel options and their qualifications, (2) revision to the fuel development plan to cover the 10-year period, (3) fuel performance model development, and (4) requirements, performance attributes, and goals for the ATW fuel. Also, there were lengthy discussions regarding the TRU-oxide fuels and whether or not that fuel type should be kept within the near term development scope. The FDWG was held in conjunction with a visit to Los Alamos by Dr. Toru Ogawa, Manager of the Research Group for Actinide Science, JAERI (Japan Atomic Energy Research Institute), who provided a seminar about the transmutation fuel-development activities in Japan.

Transuranic Fuels - An initial evaluation of <u>actinide vapor pressure</u> was conducted with specific emphasis on Am vapor pressure and the implications of Am volatility in reference to fuel fabrication. The consideration included the metal vapor pressure as well as vapor pressure of nitrides. There is very little published work on the vapor pressure of actinide nitrides. Initial assessment based on idealized models indicates that the Am pressure over AmN is only about an order of magnitude less than the corresponding vapor pressure of Am metal.

<u>Fuel-fabrication</u> process development continued. Major difficulties were encountered in the oxygen-level measurements in the Casting Laboratory glovebox. The effort to install, checkout, and begin operation of this equipment is continuing with an anticipated completion date in early April. The ventilation system for the Fuel Manufacturing Facility (FMF) is being evaluated to determine how to accommodate exhaust from the TRU fuel gloveboxes. The machine shop began the modifications of the Wilkins glovebox during this quarter. A mockup of the equipment layout for the fuel-rod assembly glovebox is being set up in the EBR-II Engineering Laboratory. Such mockups have proven to be an invaluable tool; use of the mockup in this case is expected to save weeks on the installation in FMF.

The conceptual design of the ATW-1 tests (fuel irradiation in the ATR) continued. A preliminary description of the ATW-1/ATR experiment was completed. A series of miniature fuel pins, similar in concept to EBR-II fuel pins, will be fabricated for irradiation testing. Cladding will likely be a variant of SS-316 or HT-9. Each miniature fuel pin will be stacked vertically inside of an outer pressure vessel to provide double containment for the metallic sodium present in some of the fuel pins. Various analyses were performed to determine the neutronics and thermal conditions of the test fuel in various ATR positions.

An evaluation of the helium production rate for Am-bearing fuels was performed in reference to fuel-design considerations. During transmutation of ^{241}Am, a significant amount of helium gas can be generated due to production of ^{242}Cm, and its subsequent decay by alpha emission to ^{238}Pu. In general, production is greater (by about 30%) in the thermal spectrum compared to the fast-spectrum transmutation. However, even in the fast spectrum, the helium production has a large impact on the overall gas release. The actual gas pressure depends on the amount of Am in the fuel and on the transmutation strategy (e.g. dual-strata).

A summary of the results from irradiation tests of mixed nitride fuels has been generated. The main focus of the summary is on plutonium redistribution and nitride disassociation behavior. Both the TREAT and NILOC programs indicate that decomposition of mixed nitride fuels can occur under some irradiation conditions. Based on data generated from the NILOC test, a temperature limit of 1600°C has been recommended to prevent dissociation of nitride fuel.[10]

A method to convert plutonium hydride powder to plutonium nitride (applicable to minor actinides as well) is being evaluated. The conversion requires moderate temperature and time profiles. The documentation and equipment repair to implement this method are being done. Sintering temperature and sintering time for obtaining high-density nitride pellets are being evaluated using surrogates. Also, high-density pellet fabrication schemes are being established to provide a sample for baseline out-of-pile radiation-tolerance experiments.

LLFP Target - For the long-lived fission-product target development, the installation of the glovebox in RC-1 (LANL) is the only FY01 activity. The USQD (Unreviewed Safety Question Determination) review of the project started. The review raised several issues concerning the facility modifications to Room 605 in the RC-1 Building that we need to answer before the USQD can be submitted to DOE for review. The reviewer has noted that the changes are significant and is requesting a fairly detailed design package. We are currently working these issues. Data to support some of the information requested by the reviewer were lost in the fire last year. The fire is also the cause of an exhaust system problem. We are taking more data and exploring the possibility of getting Cerro Grande fire-rebuilding money to fix the exhaust (HEPA filter/fan) problem. The unanticipated demands by the USQD and the delay in JCNNM estimates are delaying the start of construction. It is estimated that it will take two months to get the USQD approval after their questions are answered.

Materials Development

Material Test Loop - Considerable progress was made on the Material Test Loop (MTL) construction. We developed the responses to the review comments from the initial engineering review. The first revision of the test plan was submitted to classification and an initial hazard control plan was drafted. Detailed test procedures for the near-term tests are being written.

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[10] H. Blank, "Fabrication of Carbide and Nitride Pellets and the Nitride Irradiations NILOC 1 and NILOC 2," EUR 13220 EN (1991)

Drawings and documentation of all engineering analyses are being finalized in preparation for the readiness review. The major set of analyses is related to the piping, particularly in the area of the seismic response. As a result of the analyses and the subsequent design improvements, the MTL is qualified for Performance Category 1 (PC-1) seismic event (which is a 500-yr return period event).

On the construction side, certified welders completed the pipe welding, and selected welds were radiographed. All welds were visually inspected. Oxygen sensor wells were fabricated and welded into the piping; cooling water lines were installed. All auxiliary systems (cooling water lines for the heat-exchanger, gas lines, pressure sensors for gas and water systems, etc.) were installed.

Other Materials Work – Other items completed this past quarter include the following:

- A paper titled *A Kinetic Model for Corrosion and Precipitation in Non-Isothermal LBE Flow Loop*, by X. He, N. Li, and M. Mineev, was accepted for publication in the Journal of Nuclear Materials.
- We delivered some HT-9 steel plates to PSI for future in-proton irradiation.
- Revision 2 of the Materials Handbook was completed and is ready for distribution in CD-ROM form. This latest revision of the Handbook contains a new chapter (Chapter 11 on Alumina) and significant additions, revisions, and modifications to Chapter 2 (Alloy-718), Chapter 3 (SS-316L), Chapter 4 (Al-6061-T6), Chapter 5 (Al-6061 to SS inertia weldment), and Chapter 16 (SS-304L). Most importantly, these modified chapters now contain the radiation effects data obtained from base metal and weldment specimens irradiated in the LANSCE Area-A experiments.
- Decisions were made regarding the future direction of Handbook activities. It was agreed that the largest and most important activity for the remainder of FY01 was to begin the drafting of a chapter on ferritic-martensitic steels. Results of higher temperature (300°C) shear-punch tests on LANSCE-irradiated specimens also need to be added to appropriate chapters. While at Los Alamos, the Handbook coordinator assisted in the development of minimum property values (yield strength, ultimate tensile strength, and ductility) as functions of temperature and fluence for SS-304L, SS-316L SS, Alloy-718, and Al-6061-T6.
- At PNNL, tensile testing of control Mod9Cr-1Mo steels at 500°C was accomplished. In addition, in preparation for transferring the small scale testing capabilities developed at PNNL to the LANL hot cells, a shear-punch fixture was designed capable of operation at temperatures as high as 500°C.
- In collaboration with researchers from MIT and INEEL, we developed proposals for innovative materials modification for enhanced corrosion resistance, testing for system corrosion performance and kinetics with active corrosion probes and system corrosion modeling. This will enhance MTL test operations.

1.26 Transmutation Proof of Performance

Scope

Develop Proof-of-Performance requirements for an integrated transmutation system, consistent with performance objectives described in Systems Demonstrations, WBS 1.22, “Transmutation Systems Integration,” and derived against Technology Readiness Level (TRL) scale definitions to identify progressions in requirement clarification.

Highlights

- **POP Requirements Document -** The report *Accelerator-Driven Transmutation of Waste (ATW): Proof of Performance Requirements*, AAA-RPO-SYS-01-0019, was developed and issued in March. The report is a program deliverable.

Technical Progress

The document, *Accelerator-Driven Transmutation of Waste (ATW): Proof of Performance Requirements*, AAA-RPO-SYS-01-0019, was developed and issued in March. The objective in deriving these requirements is to provide an integration of TRL-based research and development activities that technically substantiate testing proof-of-performance phenomena that are representative of prototypic scales, in prototypic environments.

1.27 University Programs

Scope

University Programs involves coordination between the AAA Project and academia, and consists of three major tasks:

- **University Fellowships Program –** The Amarillo National Research Center (ANRC) will be contracted to act as the executive agency for the AAA University Fellowships Program (UFP) to select, award, and administer fellowships for ten students beginning in FY01.
- **UNLV University Participation Program –** The University of Nevada Las Vegas (UNLV) will support the AAA through “research and development of technologies for economic and environmentally sound refinement of spent nuclear fuel…” (ref. H.R. 5483, P.L. 106-377).
- **University Research Program (URP) –** A future program to create a competition, similar to that of the Nuclear Energy Research Initiative (NERI), for faculty and student research proposals (not funded in FY01).

Highlights

- **University Fellowships Program (UFP) –** The Amarillo National Research Center (ANRC) was contracted to administer the University Fellowship Program.

A Call for Applications was published in the Commerce Business Daily and distributed to more than 150 University Departments. The ANRC established a website that is linked with the LANL and UNLV AAA websites. The website includes instructions and forms for the fellowship application process, descriptions of summer work opportunities, and a brief discussion of the AAA URP.

- **UNLV AAA University Participation Program (UPP) –** A two-day workshop was held at UNLV to introduce UNLV faculty to the AAA University Participation Program (UPP) and to provide technical areas of interest for potential UNLV research. The University submitted to the DOE a proposal for the Participation Program, which was approved, authorizing the expenditure of funds. Planning meetings were held at UNLV to discuss student and faculty recruitment, promotion of the UPP, and potential new graduate programs in nuclear and radiochemical engineering.
- **Other University Programs –** Contracts were initiated with the Universities of Michigan, Cal Berkeley, and Texas to continue their support of AAA R&D. Seminars on AAA and ATW, including discussions of current and future academic programs, were presented at the Universities of Cincinnati, Wisconsin, and Minnesota.

Technical Progress

No technical progress has been made in any of these programs.